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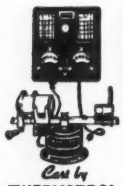

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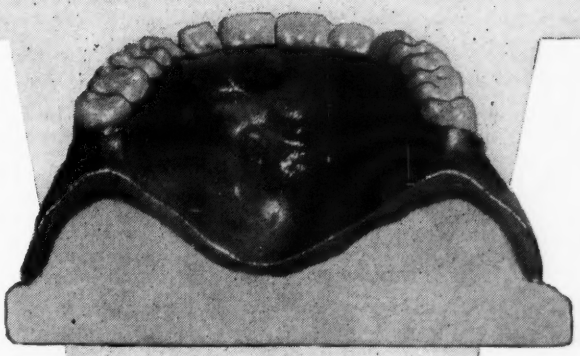

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# THE JOURNAL OF PROSTHETIC DENTISTRY

**Vol. 5** **July, 1955** **No. 4**

## THROUGH THE EYES OF THE EDITOR

Ralph C. Appleby and Wayne F. Kirchoff discuss the indications and contraindications for immediate denture service and describe a practical technique for making an impression for a maxillary immediate denture. They set up four fundamental principles which seem to be sound for this type of impression. The technique is not too complicated, and, when it is properly carried out, it will produce an accurate cast over which a denture can be made. The procedure suggested for making the postdam would have to be used with care, since it could prevent the denture from going to place if the groove cut in the cast was made deeper than the thickness of the soft tissues would tolerate.

Rudolph O. Schlosser discusses immediate denture service and the means for making immediate dentures have a more lasting value to patients. He recognizes the fact that some dentists remove sound teeth in order to place immediate dentures. This is a sad commentary on their attitude toward their responsibility to their patients, whether the removal of the teeth is requested by the patients or not. A safe attitude seems to be in the answer to the question: Would I have my teeth removed and replaced with an immediate denture if they were in the same condition of those of this patient? This attitude will lead to conservatism. In the description of his technique for making immediate dentures he urges conservative surgical procedures, and accuracy in all of the technical phases of construction. He stresses the importance of periodic inspections of the dentures and the oral condition of the patient in order that relining or occlusal corrections can be done before damage to the patient develops.

Meyer M. Silverman urges the use of pre-extraction records to prevent changes in appearance and phonetics of patients. He uses the closest speaking space as the critical record and relates this to dots tattooed in the gum tissue. This should provide a permanent record of the vertical relation of the two jaws if the dots do not change their position with the loss of structure of the ridges. He emphasizes the importance of restoring the exact vertical and horizontal overlap relations of the anterior teeth. There may be some question regarding the advisability of sacrificing balanced occlusion in eccentric positions in order to establish exactly the same vertical overlap as existed when natural teeth were in place. When the condition of the basal seats for dentures is unfavorable, every possible mechanical advantage must be used to provide stability for the dentures. Every possible pre-extraction record should be used, but this should not preclude the use of some judgment in their application.

Paul Vinton and R. S. Manly report their evaluation of masticatory efficiency of dentures during the first six months after insertion of the dentures. The various tests used seemed to indicate that chewing efficiency does not improve appreciably during the adjustment period studied, but the patients seemed to feel that they were chewing better. The dentures used in these tests were made by various people and thus have different degrees of perfection, and the number of patients involved was small. These facts suggest that the results may be inconclusive. Further study correlated with other factors involved in mastication and patient comfort seem to be indicated.

William T. Fisher discusses prosthodontics and geriatric nutrition. He points to the large increase in the number of older people in this country as an indication for further study of the needs of old people.

Aging people have different nutritional requirements from young people. Adequate dentures and guidance in the choice of a proper diet for old people will help them to have proper nutrition. Prosthodontists will do well to learn more about nutrition so their patients can be treated adequately.

Henry A. Collett describes the movements occurring in the temporomandibular joint and relates them to occlusion. He points out the great complexity of these movements and the consequent difficulty in recording them. He expresses doubt of the existence of a *true* hinge movement and seems to justify this position, but he accepts an approximation of it for very limited changes in vertical dimension. It is quite likely that, for most patients, this is a practical interpretation. However, there are some patients for whom the suggested procedure will not be adequate. He points out the variation in condylar guidance which occurs with variations in the amount of protrusion. No doubt this does cause trouble for some patients, but it can be overcome by making eccentric records at varying distances from centric position and adjusting the occlusion at these specific positions. The inadequacies of certain articulators are pointed out. It is important that these are recognized so that compensating procedures may be carried out when they are indicated. Irritation resulting from occlusion may be corrected by modifying the occlusion after remounting the dentures in the lateral and protrusive positions which are not reproduced accurately by articulator adjustment. The conclusion that "monoplane teeth forgive many of the sins of inaccuracy" may be true from a practical viewpoint, but at the same time they make the errors more difficult to detect. There can be no disadvantage in providing uniform contacts of teeth in any jaw position at which the opposing teeth may be brought together.

Eugene J. Tillman describes a technique for molding and staining acrylic resin teeth. It should produce excellent results for those who make their own acrylic resin teeth. The procedures for characterizing the teeth by staining are simple enough to be quite practical.

Carl W. Fairhurst and Gunnar Ryge report on their experiments to determine the effect of tin-foil substitutes on the strength of denture base resins. The results indicate that the strength of both self-curing and heat-curing resins is slightly greater when the molds are lined with tin foil. There was noted also a difference in the strength of the resin with different tin-foil substitutes. The effect of mold preparation on warpage is also of practical significance.

Edwin S. Smyd recognizes the need for more care in the handling of the materials used routinely in dental offices. He reports on simple experiments which illustrate the need for this care, and the effects of mishandling of certain dental materials. While the experiments might not satisfy the technical researcher, they do make clear the facts that the physical properties of materials are affected by the way in which they are used, and that a knowledge of their behavior under varying conditions is essential to their effective use.

Joseph S. Landa reports his analysis of current practices in mouth rehabilitation. He discusses the purposes and various procedures used currently in dental practice. His principal concern is for the effects of increasing the vertical dimension of occlusion in order to improve the appearance of the patient. He feels that the biologic and mechanical factors must be considered when changes in the vertical dimension of occlusion are made in order to avoid serious damage to the health of the patient as well as the masticatory system. He points out a physiologic-pathologic balance which must be recognized in order to avoid trouble for the patient. He correctly urges conservatism in rehabilitating procedures and has sound reasons for this attitude.

David A. Hagerman and Sumter S. Arnim discuss the relation of the gingivae to clinical crown and bridge prosthodontics. Recent research relating to the attachment of the gingiva to the tooth is reviewed. With this background, it is concluded that fixed restorations may be extended below the free margin of the gingiva with safety, provided certain critical conditions are satisfied. One of the most important of these was cited as effective personal oral hygiene. A method for maintaining satisfactory oral hygiene is described. The conclusions bear out the validity of current clinical practice.

Earl Pound suggests a simple means for splinting teeth separated by short spaces. The method should provide both support and stability for partial dentures in these situations. It seems to have definite advantages where it is indicated.

Robert S. Ledley describes a method for analyzing the forces applied to prosthetic appliances and their supporting structures. He considers both the direct forces and the reactive forces involved. The study extended to the dispersion of the forces and the stresses and strains induced by them. By this method, the structural requirements of a given restoration for a given individual can be determined.

Edwin H. Smith, Jr. describes a technique for making display models. The procedure is quite simple and requires the use of materials and equipment that are readily available. This appears to be an easy solution to one of the time-consuming parts of the preparation of material for clinical demonstrations and exhibits.

T. S. Malson describes in detail the procedure for making a complete upper denture and obturator for an edentulous patient with a congenital cleft palate. As he describes it, the problem is not as difficult as it might seem. It involves a consideration of the same basic principles involved in making routine complete dentures and in the handling of the usual dental materials. He points out certain factors which favor successful treatment of these patients. The technical procedures suggested are practical and do not require special skills.

John B. Lazzari describes the procedures used for the construction of splints to support the lips of patients afflicted with Bell's palsy. Fortunately, the need for this type of appliance is not common, and when it is needed, the appliance is not difficult to construct.

*—Carl O. Boucher*

# THE GREATER NEW YORK ACADEMY OF PROSTHODONTICS

Jerome M. Schweitzer, D.D.S., First President, Greater New York Academy of Prosthodontics.
(Blackstone Studios, New York.)

The Greater New York Academy of Prosthodontics was formally organized on Dec. 6, 1954, in New York City, to meet the needs of dentists located in the eastern part of the United States who are interested in the practice of prosthodontics and its related sciences. The Academy's aim is to foster better understanding among the various specialty groups in dentistry, and to promote and stimulate further research in prosthodontics and its related fields. Membership is by invitation, and is not confined to the New York area.

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# IMMEDIATE MAXILLARY DENTURE IMPRESSION

RALPH C. APPLEBY, B.S., D.D.S., M.S., AND WAYNE F. KIRCHOFF, D.D.S., M.S.

*College of Dentistry, State University of Iowa, Iowa City, Iowa*

AS EACH DAY PASSES, more and more people are becoming aware of immediate denture service. An immediate denture is one in which the denture is constructed before all of the remaining teeth are removed. The denture is inserted immediately after the surgical procedures are completed. The technique for the construction of immediate dentures is taught in every dental college in our country; numerous excellent articles on immediate dentures have appeared in our various dental publications; yet there still are dental offices in which this invaluable service is not practiced. In those offices in which it is practiced, both the patient and dentist recognize, understand, and appreciate its great value.

Back as far as 1860 or earlier, the value of the immediate denture was recognized, as shown by Richardson[1] when he stated:

> "The value of temporary (immediate) sets of teeth to the patient on the other hand is unquestionable. They fulfil in a tolerable degree, all the requirements of artificial teeth under any circumstances, if we except that of mastication, this function being, more or less imperfectly performed with such pieces."

Sears[2] says, "In cases where some of the natural teeth remain in place, it is wise to consider the advisability of constructing dentures before the teeth are removed."

Hughes[3] says:

> "The practice of providing our patients with prosthetic dentures immediately following the removal of the last remaining natural teeth is no longer a novelty. It is now routine procedure in most dental offices. It is no longer regarded as a special service limited to certain carefully selected cases."

Writing on the subject of immediate dentures, Schlosser and Gehl[4] state:

> "It might be said with some exceptions they are indicated for practically all patients in whose mouths a complete and thorough examination has revealed a condition of the teeth that would warrant their

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removal in order that the best interests might thus be served—that is, their physical appearance. Among the exceptions that might be cited are those cases in which the age or general physical condition of the patient is such as to make it inadvisable to extract six or more teeth and do the necessary surgical preparation all at one sitting."

This opinion seems to be most prevalent throughout all the literature. It is a service which the informed public is demanding; and with our newer materials and modern techniques, patients are able to receive a service which is very gratifying and which no other service in dentistry is able to surpass.

### INDICATIONS AND CONTRAINDICATIONS FOR IMMEDIATE DENTURE SERVICE

Smith[6] in his outline for construction of complete dentures summarizes the indications and contraindications for immediate denture service as follows:

"A. Indications:

"1. The public is beauty and age conscious and demands this type of service.

"2. Prevents formation of adverse changes which develop if an individual goes without teeth for some length of time—loss of muscular perception for centric relation, loss in muscle tone, loss in facial appearance due to lost vertical dimension.

"3. The patient will learn to wear dentures with less difficulty.

"4. The occlusion of the remaining teeth can be used in many cases as the guide in determining vertical dimension and in registering centric relationship. (This is not true for cases (1) where marked abrasion has taken place and recovery of lost vertical dimension is desired; (2) where interlocked interdigitation of the teeth guides the mandible into eccentric rather than into centric relationship with the maxilla.)

"5. Muscle tone remains normal providing normal facial length has been maintained by the opposing teeth.

"6. Esthetics for the case are more easily attained because the operator has a guide to follow when arranging the teeth.

"7. The denture acts as a splint, aids in controlling bleeding and in protecting the sockets.

"8. Better residual ridges seem to result, and it is claimed by some that resorption of bone will be less. (This latter statement should be qualified. If conservatism is practiced and only a minimum amount of bone is destroyed in the extraction of the teeth, the statement is probably true. However, if radical measures are followed, and if an extreme amount of the labial and the buccal plates of bone are removed, an excessive amount of resorption may be expected.)

"9. Usually there is less postoperative pain.

"10. It takes advantage of the patient's sense of pride, and he will put forth great effort and will himself more readily adapt to the change from natural to artificial dentures.

"B. Contraindications:

"1. General Health. It is not wise to advise this service for the patient who is feeble or who is in poor health.

"2. Pathologic conditions about the teeth. If these conditions are of such nature that extreme resection may be necessary or that only two or three teeth should be extracted at one time, immediate denture service is contraindicated.

"3. Age. More adaptable for the younger or middle-aged patient than for the elderly.

"4. Appreciation on the part of the patient. If the patient is not fully appreciative of the service one is going to attempt to render, he will not give the cooperation necessary.

"5. Indicated more for the maxillary arch than for the mandibular since the upper denture is a greater factor as regards esthetics; also, better results usually are more attainable with the upper denture than with the lower. In case both upper and lower dentures are being made for a patient, physical shock may make it advisable that a period of several days elapse between the extraction of the maxillary teeth and insertion of the upper denture, and the extraction of the mandibular teeth and insertion of the lower denture."

## IMPRESSIONS

Jordan[6] said, "Impressions of jaws receiving full dentures should be made without undue compression of the soft tissues and should include a true copy of the outline and contour of the relaxed buccal and labial vestibules." Mitchel[7] states, "Impressions used in immediate denture construction have, as a rule, been of the type known as snap impressions in which little effort is made toward muscle-trimming or tissue control." This has been true in the past, and we strongly suspect it holds true today. It is most certainly one of the major causes of post-insertion visits to the dental office. With reasonable skill and the application of the basic principles of edentulous impressions, with certain variations, these visits can be eliminated with the exception of normal follow-up visits. These are arranged for twenty-four hours after insertion, for suture removal, and periodic visits to check occlusion and resorption. Swenson[8] says, "There are several acceptable methods of making impressions. It can be done with an alginate, compound and plaster, with compound and hydrocolloid, with compound and zinc oxide-eugenol paste, or with all hydrocolloid." His method of choice is an impression made with alginate in a metal tray that is trimmed or built up in wax or both as is necessary.

There are certain basic fundamental principles of impression making which the prosthodontist seeks to achieve, whether it applies to an edentulous impression or for an immediate denture. These principles can be summarized as follows: (1) *Areal Coverage*: To cover as much denture-bearing area as possible, within the normal functional movements, for denture support. (2) *Border*: To develop a border around the entire denture, section by section, within the limits of tissue tolerance. (3) *Valve seal without interference with functional movements*: Establishment of a border which harmonizes with the anatomic and physiologic landmarks surrounding the denture. Provision has been made not only for valve seal, but also for maximum lateral stability. (4) *Accurate adaption to the underlying tissues without injurious displacement.* A carefully muscle-trimmed border insures contact with, but not impingement on, the border tissues. A final wash material, as soft as, or if possible softer than, the tissues being registered, provides for accurate adaption without injurious displacement and for equitable distribution of stress.

## THE IMPRESSION TECHNIQUE

The technique which will be described is currently in use at the State University of Iowa Dental College; and although we shall confine our description to the upper impression, the same technique will lend itself equally well to the lower arch, provided the applicable components are integrated with the sound and accepted parts of an edentulous technique.

After all preliminary work such as clinical and radiographic examination and pre-extraction records are completed, the impressions may be made. The tray is selected for the preliminary impression from stock trays constructed especially for this purpose. It is a tray adapted to retain an alginate impression material. The tray is trimmed and/or soft wax is added to allow it to conform as nearly as possible to the contours of the mouth. The impression is made in an alginate handled according to the manufacturer's instructions concerning mixing, water temperature, and water-powder ratio. After the material is sufficiently set, it is removed from the mouth and carefully examined for any imperfections, and for proper border extension. Any excess is trimmed away, and the impression is rinsed and dried with a blast of air and poured immediately in artificial stone. Cast imperfections can be avoided by vibrating a mix of stone over the impression of the tissue and the teeth, rinsing it out with water, and drying this surface with air immediately before pouring the cast. This is especially important if the patient has a very viscid and ropy saliva. To eliminate any possible distortion of the alginate by boxing or inversion, stone is poured into the impression of the teeth and soft tissue and allowed to harden in an upright position. Then stone is mixed to form the base, and the first part of the cast is inverted and placed upon the new mix of stone.

## THE INDIVIDUAL TRAY

A border outline is drawn on the preliminary cast with a pencil. The outline is made 3 or 4 mm. short of the relaxed, reflected tissues in the buccal and labial vestibules, and coinciding with the vibrating line approximately at

the beginning of the soft palate (Fig. 1). Shredded wet asbestos is adapted around the teeth on the cast (Fig. 2). Then one thickness of baseplate wax is adapted over the entire cast, and terminated at the pencil outline (Fig. 3). The purpose of the wax shim and asbestos is to provide space for an alginate impression material which is used for the final impression.

A quick-curing resin tray is constructed over the wax shim on the preliminary cast. When the resin tray is removed from the cast, the wax shim

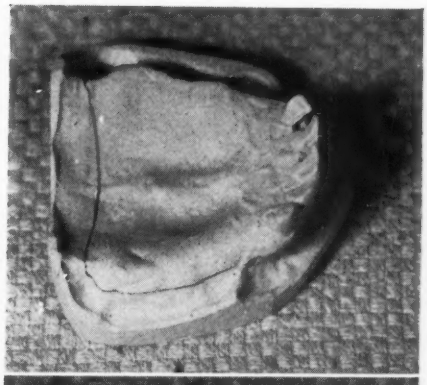

Fig. 1.

Fig. 2

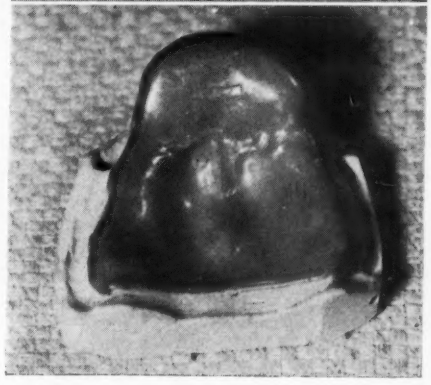

Fig. 3

Fig. 1.—The preliminary cast is outlined for a spacer for a tray. The outline is made 3 to 4 mm. short of the reflections and exactly on the vibrating line.

Fig. 2.—Wet asbestos fibers are placed over the teeth.

Fig. 3.—One sheet of baseplate wax is adapted over the cast and the asbestos fibers to form a spacer. It is trimmed to the outline on the cast.

will adhere to the tray. The shredded asbestos is removed from the tray, and the borders of the tray are trimmed to the wax shim, but the wax shim is not removed at this time (Fig. 4). The tray is placed in the mouth to make sure that the borders are approximately 3 to 4 mm. short of the reflections, and that the posterior extension is correct. The posterior border is trimmed accurately so that it terminates just anterior to the movable part of the soft palate, yet covers the immovable area just anterior to the vibrating line. Then the wax shim is removed, except for three "stops" (Fig. 5). These "stops" are arranged so there is one on the crest of the ridge just anterior to each maxillary tuberosity and one in the midpalatal section, just posterior to the remaining teeth. The "stops" will prevent the tray from being seated too close to the mucous membrane, and will provide a stabilizing effect on the tray when

**Fig. 4**

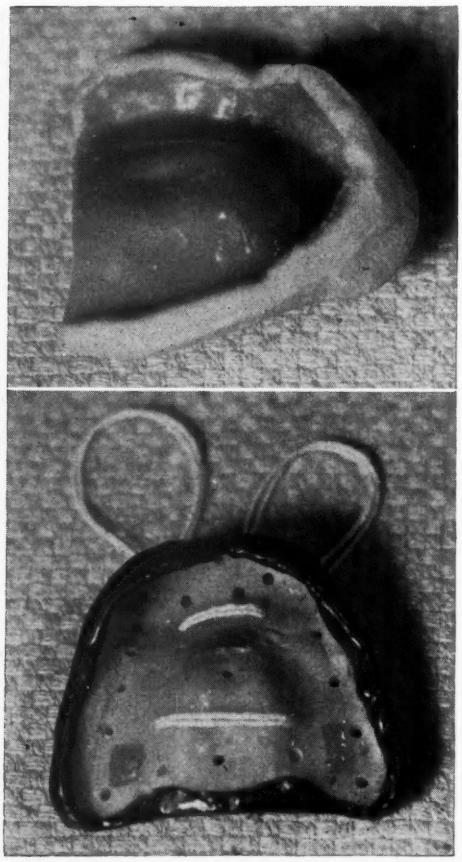

**Fig. 5.**

Fig. 4.—A quick-cure resin tray is formed over the wax spacer and removed from the cast together with the spacer. The tray is trimmed to the edge of the spacer.

Fig. 5.—The borders of the tray are formed in modeling compound after the spacer is removed. Note the three "stops" which are used to position the tray for forming the borders. The string is used to aid in the removal of the final impression from the mouth.

the final impression is being made. The positions of the "stops" may be changed to suit the mouth conditions. For example, a wax stop would not be placed directly over soft, displaceable tissue.

Low-fusing stick modeling compound is traced on the borders of the tray and muscle trimmed, section by section (Fig. 5). The compound is purposely muscle trimmed approximately 1 mm. short of the relaxed tissues in the buccal and labial vestibules. This will allow sufficient space for the final alginate wash. An impression made in alginate alone will not allow the operator to be certain of the proper border contour and posterior extension to the vibrating line. This is necessary in order to create a border seal.

The low-fusing stick compound is added section by section, starting with the labial flange section which extends from the buccal frenum to the buccal frenum. In order to mold the compound in this section, the upper lip is draped downward and inward over the softened compound. Care must be exercised to avoid over-extension which would make adjustments necessary after the denture is inserted.

The buccal flange section, which extends from the buccal frenum to the distobuccal portion of the maxillary tuberosity, is muscle trimmed next. This is done by draping the cheek downward and inward around the softened compound. The patient should move the mandible from side to side while the compound is soft to make sure that the denture will not interfere with the ramus during the lateral excursions of the mandible.

The final section extends from the hamular notch on one side of the mouth along the vibrating line to and including the hamular notch on the opposite side. The hamular notches and the vibrating line are marked in the mouth with an indelible pencil. When the compound is added to this portion of the tray and inserted, the indelible pencil line will transfer to the compound. All compound posterior to this line is removed, and all indelible marks are removed from the mouth. The indelible pencil is then traced along the posterior aspect of the compound, and the tray is reinserted. This line will transfer to the mucous membrane so that the posterior accuracy of the length of the tray may be checked. While this section is being muscle trimmed, the patient is asked to open and close the mouth to make sure that it does not impinge upon the pterygomandibular raphe distal to the hamular notches.

Approximately twenty-five perforations are made in the tray with a No. 8 or 9 round cherry bur, in order to ensure adherence of the alginate impression material to the tray. A piece of string or dental floss is threaded through several of the perforations to facilitate removal of the tray after the impression is made (Fig. 5).

### THE FINAL IMPRESSION

The patient is instructed to rinse his mouth with a mixture of a few drops of aromatic spirits of ammonia in a glass of water. This is particularly important if the patient has a viscid and ropy saliva.

The alginate impression material is mixed according to the manufacturer's directions, placed in the tray, smoothed with a wet finger, and carefully placed

in the mouth. In seating the impression, extreme care must be taken to avoid trapping air in the labial and buccal vestibules. After the impression is seated, the labial and buccal frenula are freed. The operator must make certain that the patient's facial muscles are completely relaxed, and that the tray is retained in position until the alginate has set completely. The impression is then carefully removed by means of the previously attached string. Any excess impression material extending beyond the distal end of the tray is trimmed away. If the impression is acceptable, it is treated in the same manner as the preliminary impression, and the final cast is poured. If the impression is not acceptable, the alginate must be removed entirely, and the impression must be remade.

## THE POSTDAM

A postdam is placed in the final cast. Maison[9] says, "When scraping the cast for post-damming, always bear in mind and allow for the dimensional changes in the denture base due to shrinkage of the base material. The changes vary with the bulk of the material, and amount to approximately one-half to one millimeter." A small round instrument is used to locate the vibrating line in the mouth. Since the cast has the proper posterior extension, all that remains is to determine the width and amount of displacement of the tissues in the postdam area by palpation. By using a No. 8 round bur, a series of holes are made on the cast along the posterior portion of the postdam area. These holes are made approximately one-half of the depth that the tissue is displaceable. The holes are connected by means of a suitable hand instrument, beginning at one hamular notch and continuing across the palate to the other. This postdam is beveled gradually from its deepest part anteriorly toward the hard palate, following the predetermined contour of the postdam area. Thus, any adjustment which might have to be made on the finished denture will not break the established seal.

## SUMMARY

The technique described may consume a little more time in making the impression, but the results obtained more than justify the use of this time. The procedure provides for (1) areal coverage, (2) an accurate denture border, (3) a valve seal without interference with functional movements of oral structures, (4) accurate adaptation of the denture to the tissues without injurious tissue displacement, and (5) determines the correct posterior extension of the denture, (6) creates a postdam which not only completes the valve seal but which also compensates for dimensional changes in the denture base due to shrinkage during processing, and (7) minimizes postinsertion adjustments.

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# A CONSIDERATION OF SOME OF THE MAIN FACTORS CONTRIBUTING TO THE DEVELOPMENT OF MAXIMUM EFFICIENCY AND TO THE PROLONGATION OF THE SERVICE LIFE OF COMPLETE IMMEDIATE DENTURES

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WHILE TO A LIMITED EXTENT the making of immediate dentures has been practiced for nearly a hundred years, this practice has gained greatly in popularity during the past twenty-five years. Although it possesses many advantages for certain types of patients, there are a number of instances in which it is definitely contraindicated.

Into this category belong, first of all, those patients of advanced age and lowered resistance to whom the mere suggestion of multiple extractions may constitute a psychologic shock, or to whom the ensuing shock that occasionally follows multiple extraction and a radical surgical reduction of the alveolar bone in the preparation of the mouth for the reception of immediate dentures might prove to be beyond the limit of endurance. Second, immediate dentures are definitely contraindicated for patients suffering from tuberculosis, diabetes, or other debilitating diseases. Third and last, they are not indicated for patients in whom a comprehensive visual, digital, and radiographic examination reveals that the remaining teeth, the bony process in which they are still firmly held, and the surrounding oral mucosa are in sound health and that the teeth themselves are in reasonably good alignment. Such conditions would in most instances warrant their retention and use as abutments or stabilizing factors for some type of fixed or removable partial denture.

It is my belief that the first two of these classifications have received sufficient attention in our dental literature to dispense with further discussion. The third or last of these classes, however, is one which, in my judgment, requires further consideration and special attention.

From personal observation of many patients during the past fifteen years and after a careful recording of their case histories, I have come to the conclusion

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that all too great a number of patients have been and are being made completely edentulous long before they should be subjected to such treatment. For many of these individuals, such action could undoubtedly have been postponed for a considerable period by a more rationally conservative or preventive treatment.

My belief in this respect has been substantiated, on the one hand, by the excessive and more rapid resorption that has followed the wholesale extractions and the so-called radical surgical reduction of the denser bone of the alveolar ridges as this has been done in preparing the mouths for the reception of the immediate dentures, and, on the other hand, by the truly gratifying evidence found in the mouths of hundreds of other patients, ranging in age from 60 to 75 years and over who had been wearing well-fitting, precisely constructed partial dentures for from five to fifteen years with great satisfaction and comfort.

These are the findings which have prompted and encouraged me to place so much emphasis on the opening portion of this paper. I feel confident that there are many who have had similar experience and as a result share with me the views I have expressed. It is my fervent hope that its significance may be properly evaluated by all as an integral part of preventive dentistry to which we, as members of our chosen profession, should rededicate our daily efforts from time to time.

Let us now take up the matter of how we should proceed to develop the maximum efficiency and by what means we can prolong or extend the service life of immediate dentures. At this juncture it seems appropriate to call attention to a well-established fact, namely, that one of the prime requisites for successfully conducting a professional practice is the adoption of a well-organized treatment plan in which the various clinical and laboratory procedures involved are carried out in orderly sequence. The same basic principles apply to any presentation before a professional group, whether it be a specially prepared paper, a clinical demonstration, or a free and open discussion pertaining thereto. In this instance I will reverse the old well-known adage and set out to *preach* what I have been in the habit of *practicing.*

When, after a comprehensive visual, digital, and radiographic examination, a proper diagnosis has been made, and, as a result of the findings thereby revealed, it has been established that the patient's best interests would be served by an immediate denture, the next step in the clinical procedure is the making of a primary impression in order to make a study cast (Fig. 1). Either a reversible hydrocolloid or an alginate material may be used. An impression should also be made for the pouring up of a cast of the opposing teeth with which those of the denture are to be occluded. If this impression is to be used for the master cast, however, it would be best that any needed corrections to the incisal edges or occlusal surfaces of the teeth to be retained precede the making of the impression. This applies solely to cases where there is to be one denture only. The procedure may be varied by mounting both casts on an adjustable articulator, thus permitting a further study and a more thorough diagnosis of the existing conditions. It would also serve for a so-called prognostic setup of the posterior teeth and help in selecting teeth of proper form and size.

It is, of course, possible to correct the teeth as necessary before any impressions are made; there are specific advantages to be gained, however, by a careful

study of the mounted casts first. Next the prevailing undercuts or excessive bony prominences should be studied, both in the mouth and on the casts. The magnitude of the labial vestibule should be noted to determine whether a labial flange may be tolerated without undue displacement of the upper lip. When it is judged that the bony prominences might offer interference to the insertion or removal of the completed denture, these should be reduced well in advance of the final impression to allow sufficient time for the healing of the operated areas. The aim should always be to hold such reductions down to a minimum.

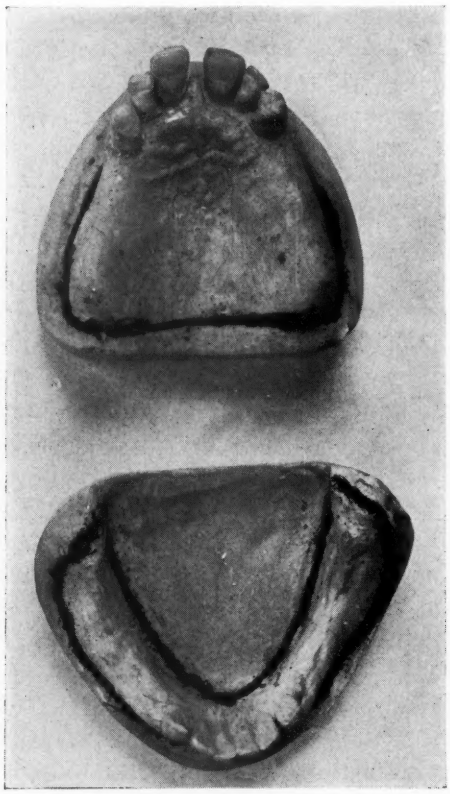

Fig. 1.—Study casts with the scribed outline of the denture area.

Routinely, it is advisable to extract the bicuspids and molars at from three to six weeks prior to the primary impressions, at which time it may be possible to undertake the reduction of the prominences of the posterior segments of the ridge; since, however, this often results in some needless reduction, it is better to defer this part of the operation until after study of the mounted casts. In the intervening period, the operated areas will heal over and be in a much better condition to support and tolerate the denture.

## CONSTRUCTION OF THE DENTURES

When the study casts are to be mounted, I have frequently poured a duplicate cast in the same impression after a careful separation. While this is optional and may be omitted, it does allow the second cast to be used in tray preparation and thus saves the original cast from possible mutilation. The tray is used in the making of the final impression. From this point on, the subsequent steps are carried out in orderly sequence as follows:

1. Molding the individual acrylic resin tray over the prepared study casts. (Fig 2).

2. Checking the prepared tray in the mouth for proper conformity and correct extensions of the flanges and the postpalatal border (Fig. 3).

Fig. 2

Fig. 3

**Fig. 2.—Wax shims adapted to the study casts preparatory to molding the cold cure acrylic resin trays.**

**Fig. 3.—Acrylic resin trays with occlusion rims attached in the edentulous regions, and with perforations in the dentulous regions.**

3. Building up the tray borders with a low-fusing modeling compound tracing stick and subjecting this to a functional adaptation. If the latter is to be done under closed mouth conditions, an occlusion rim must be attached to the tray.

4. Making the final impression, which, at the option of the operator, may be done with or without the use of an attached occlusion rim. I prefer to use

the rim because it permits a combination of the open and closed mouth muscular action, resulting in better molding of the borders in compliance with the functional needs (Fig. 4).

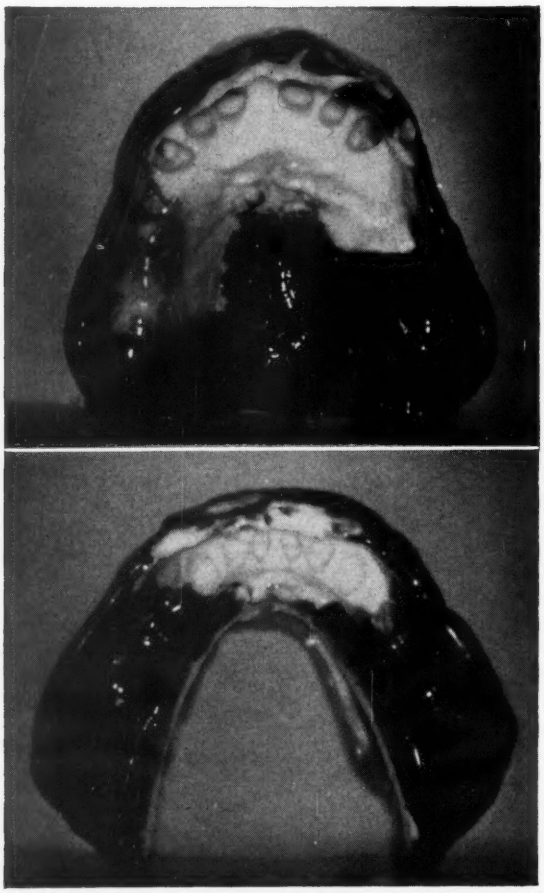

Fig. 4.—The final impressions made of modeling compound in the edentulous regions and of alginate in the dentulous regions.

5. Boxing in the impression and pouring up the master casts.

6. Checking the extent of the free marginal gingiva in the mouth and the depth of the pockets about the teeth (Fig. 5). This is easily determined by slipping one point of a pair of small tweezers under the free tissue and closing the tweezers gently. This is followed by scribing marks on the corresponding areas of the master casts to indicate the amount of trimming that is to be done after the teeth have been cut off, in order to permit the placing of the dentures without requiring any trimming of the bone after the teeth have been extracted. (This does not preclude the smoothing down of sharp points of the septa.)

7. Making the partial baseplate to be used in the registration of the acceptable vertical dimension of the denture space and of the positional relations of the jaws. While it is possible to obtain these registrations with a single set of base-

plates, it will save considerable chair time if separate baseplates are made for each of the three records required (Fig. 6). (This is another point that is left up to the operator's choice.)

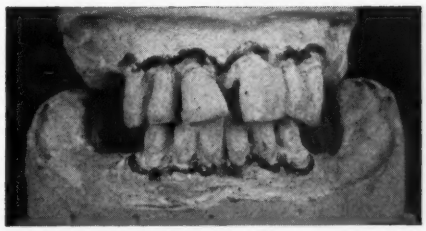

Fig. 5.—The master casts marked to indicate the extent of the free marginal gingivae for a guide for trimming the casts after the teeth have been cut off.

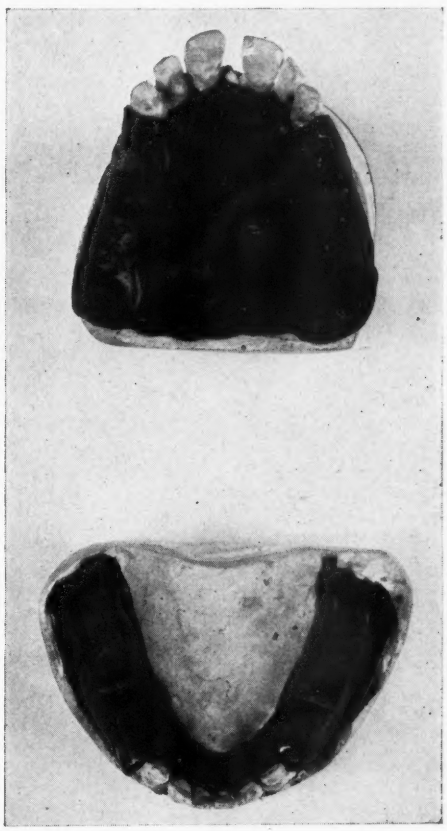

Fig. 6.—Master casts with their baseplates and occlusion rims.

8. Obtaining the above registrations. The rest position of the mandible, with the lips in unstrained contact, is used as the *position of reference* in determining the acceptable vertical dimension of the denture space and is used to provide

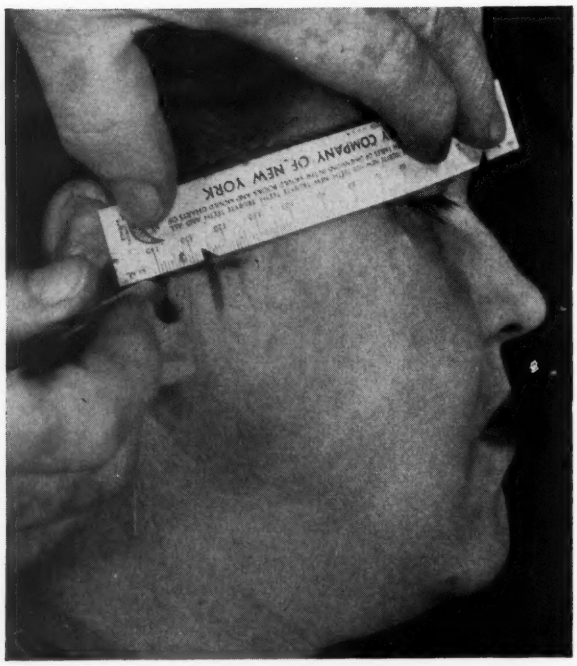


Fig. 7.—Marking the location of the axis of opening of the mandible for the adjustment of the face-bow.

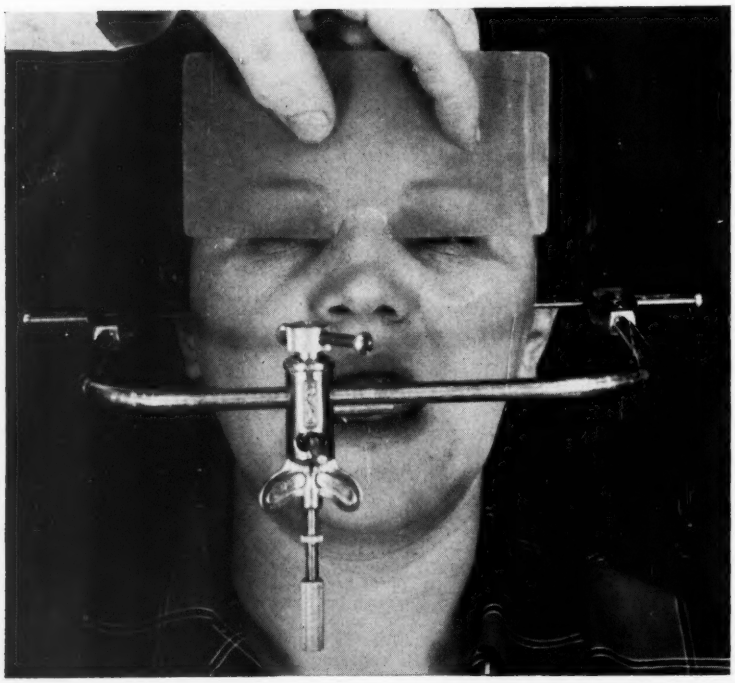

Fig. 8.—Checking the position of the face-bow for alignment parallel with the pupillary line.

the interocclusal clearance or free-way space. It is this vertical dimension that must be subsequently incorporated in the record of the centric relation.

The first of the three records to be obtained is the face-bow record. This is used to mount the maxillary cast on the articulator (Figs. 7 and 8). The next is the centric relation record; this is used in the mounting of the mandibular cast (Fig. 9). The third record is the one which registers the protrusive relation of the mandible (preferably a 6 mm. range). It is used to set the mechanical condylar indication of the articulator. To avoid displacements of the supporting tissues during these registrations, all records should be obtained in the absence of strain.

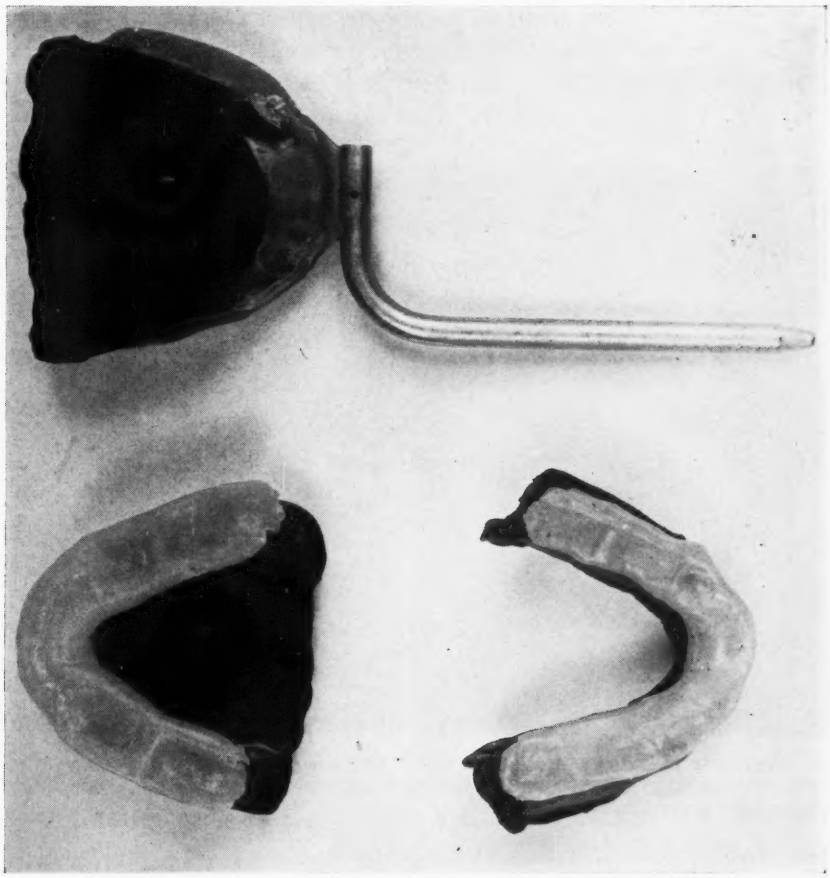

Fig. 9.—Baseplates and records; (above) with the face-bow fork; (lower right) the centric relation record; (lower left the protrustive relation record.

9. Selecting the teeth, for harmony of size, form, and color.

10. Setting up the posterior teeth as for partial dentures.

11. Trying in the partial setups as follows: checking the accepted vertical dimension of the denture space and its effect on the general appearance, particularly in front view and profile; checking the occlusions of the teeth and rechecking

the selection; checking the interocclusal clearance or free-way space; making a final study of the patient's anterior teeth, their size, form, color, and arrangement, noting the extent of the vertical and horizontal overlap. The over-all purpose is to determine whether these conditions are to be reproduced or in what manner they should be modified to produce the best possible results for function and appearance.

12. Completing the setup of the teeth, and preparing the dentures for processing. Cut off the anterior teeth from the cast on one side of the median line as indicated by the markings referred to in step 6. While using the teeth on the other side as a guide, set the replacement teeth in accordance with the suggestions made in step 11. When this has been done, repeat the procedure on the other side. Check the various occlusions for proper contacts and for clearance during mandibular excursions from and to centric relation. Complete the waxing, carve the festoons and rugae, and process the denture.

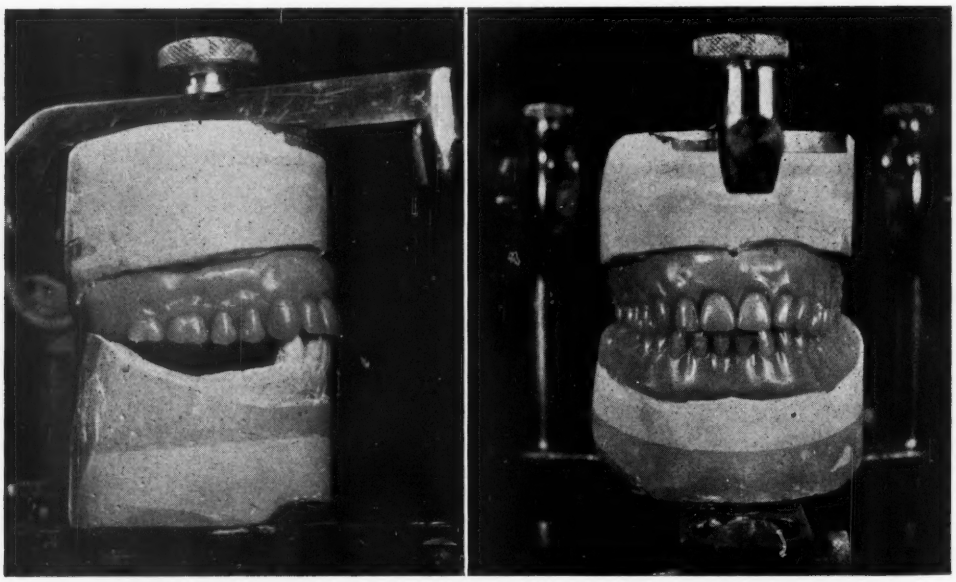

Fig. 10.—The completed dentures. (Left) The upper denture in relation to the lower study cast. Note the normal vertical and horizontal overlap of the anterior teeth. (Right) The dentures in occlusion.

13. Processing the denture. After the denture has been processed and allowed to become thoroughly cooled, separate the denture from the investment but do not remove it from the cast. Trim the excess acrylic resin from about the teeth, replace the cast accurately upon its index and fasten it securely. Check for occlusal disharmonies that may have resulted from minor volume changes during the processing. These are now disclosed by using articulating paper and eliminated by judicious grinding to establish a more perfectly balanced occlusion. When both upper and lower denture are being made, it is advisable to process the upper one first, replace it on its index as above; and then improve the occlusions by correcting the resetting of the lower teeth before the denture is processed. It is then

replaced on its index in a similar manner and, after the major disharmonies have been removed by grinding, the occlusions are milled-in by using abrasive paste. In this manner, the balancing contacts are still further improved. Finally, the dentures are separated from their casts, trimmed, and polished (Fig. 10).

It is advisable to remount the dentures on the articulator for subsequent check-ups or adjustments. This can be be done easily by making an articulator record of centric relation after the occlusions have been balanced and using this record for remounting the polished denture.

14. Inserting the denture. The extraction of the anterior teeth, the insertion of the denture, and the instructions to the patient relative to the use and care of a set of artificial teeth are the final steps (Fig. 11).

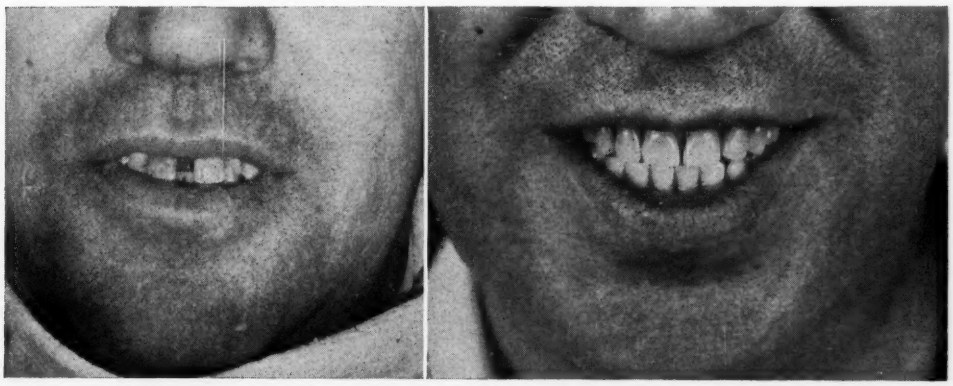

Fig. 11.—The appearance of the patient's mouth, (left) with natural teeth, (right) with immediate dentures.

Because the method of preparing the individual trays and the functional molding of the design or pattern for the borders of the denture as described resulted in proper extensions and good peripheral adaptation, and also permitted the testing of the base, thus formed, before the impressions were completed with the alginate material, little or no difficulty is experienced in placing the immediate denture after the teeth have been extracted. Because the records were made with tissue-supported baseplates not subjected to biting pressure, we had, in addition to the proper extension and good border form, the third major factor so necessary to insure adequate retention for the denture, namely, an intimate surface adaptation.

By the elimination of the occlusal disharmonies and as a result of the full freedom for the mandibular excursions to any lateral, protrusive, or intermediate positions as these are assured by the judicious spot grinding and milling-in, the lateral strains and stresses are reduced to a minimum and the stability, retention, and comfort of the patient are enhanced.

After the denture has been inserted, the patient is instructed to return in twenty-four hours, whenever possible, and not to remove the denture in the interim. At this time the denture is carefully removed, both the mouth and the denture are carefully inspected, and any needed adjustment is made. The patient is told how to place and remove the denture and how to care for it. He is told to report at

regular intervals during the initial period of adjustments and then to return in three to six months for subsequent inspection.

The fact that I have placed myself on record in favor of conservative procedures in the preparation of mouths for the reception of immediate dentures should not be construed as meaning that I am opposed to needed surgical intervention, for I am fully cognizant of the advantages of all phases of modern surgical procedures. This, however, still does not change my attitude toward premature extractions of teeth whose retention and usefulness might be indefinitely prolonged.

On the whole, I have found that resorptive changes seem to occur more rapidly in mandibular ridges, particularly when the anterior segment of the ridge is rather bulbous. In such cases I have deviated my procedure somewhat, by having this condition reduced slightly and making what I have called a "near-immediate" denture. An acrylic resin baseplate is used for setting up the teeth as though for an immediate denture; after the teeth have been extracted and the surgical reduction has been made, while the anesthesia is still effective, I have made a reline impression in the acrylic resin base on which the teeth have been set up. This enables me to complete the denture within a few hours and to place it within twenty-four hours.

At this stage I anticipate that the question has arisen as to what the real factors are that were referred to in the title of this article as contributing to the development of maximum functional efficiency and the prolongation of the service life of the immediate dentures. In reply to such a question, which has already been answered in part, and at the risk of repeating myself, I submit the following for careful consideration. Basically they are the same factors that have and will produce these desired results in all types of denture work, whether it be an immediate or a subsequently made complete, or partial denture. There are, however, these certain specific factors that are especially effective in the construction of as well as during the servicing of the dentures after they have been inserted.

## FACTORS TO PROLONG THE SERVICE LIFE OF DENTURES

Among the ones that may be said to deserve special mention are, first, the conservation of as much of the alveolar ridges as is possible; second, the functional or physiologic molding of the pattern for the borders of the dentures, which more or less automatically produce correct extensions of the flanges as well as a perfect peripheral adaptation that, in turn, requires little or no subsequent alteration; and last, the perfectly balanced occlusion built into an acceptable vertical dimension of the denture space, coupled with a well-established freedom for all normal mandibular excursions. All of these tend to minimize the strains upon the supporting tissues.

That all of the afore-mentioned factors may be rightfully adjudged as contributing to the functional efficiency and the prolongation of the service life of immediate dentures can hardly be the subject of much controversy. To this statement it is but fitting that something should be added about the procedures that will be required to extend or restore the service life of these dentures when, as a result of the natural processes of resorption and other changes that do occur

in the supporting tissues, the stability and retention become impaired. I have always held to the belief that one reason why dentures, constructed in accord with the principles as I have described them, have given such satisfactory service is that a denture base that is in intimate contact with its supporting tissues and for which this adaptation has been worked out or developed with a full consideration of the biologic factors involved, and where such a well-fitting base was coupled with a perfectly balanced occlusion, built into a denture space of relatively normal vertical dimension, will do much to restore and retain their tone and structural form, because it serves to stimulate not only the tissues upon which it rests or is supported by but also the adjacent muscular structure as well.

In the course of my regular routine, I have had occasion to examine the mouths of many patients who have worn immediate dentures with a great deal of satisfaction and comfort for periods varying from two to six years and, in a few instances, for even a longer time. I have also seen many other patients during these years who told me of less favorable results with immediate dentures. In most of the latter cases, they reported that they had to have their dentures refitted, remade, or replaced with subsequent dentures after but a few months and, in some instances, after just a few weeks; in still others, the immediate dentures had to be relined at the time of their original insertion.

I have cited these cases not in a spirit of criticism, but merely to state the facts as I have observed them. It would be difficult indeed to designate the specific reasons or causes for these unsatisfactory results; yet I do believe that I am justified in bringing these conditions to your attention. In my opinion, it would have been possible, at least in a number of these cases, to obtain more gratifying results if the more conservative as well as a more precise method of clinical and laboratory procedures had been employed in their fabrication.

As previously stated, in all cases it is advisable that, after the initial period of adjustment has passed, the patient be recalled at regular intervals for a periodic checkup and needed subsequent adjustments, as least once every six months. It will then be a comparatively easy matter to make minor adjustments which will help to keep the dentures functioning satisfactorily and thus add to the patient's comfort and well being.

## RELINING

Whenever it is found that the stability and retention of the denture seems to be impaired to an extent which may not be overcome by minor corrections, it will still be possible to prolong the service which the denture can render by relining or combining the reline impression with a duplication of the denture.

If proper precautions are taken to avoid an improper placement of the denture during the making of the reline impression in either modeling compound or one of the impression pastes, the denture can then be either relined or duplicated, depending on the method preferred by the operator. As an alternative the impression may be made in one of the special self-curing acrylic resin materials which harden in from twenty to thirty minutes and thus virtually constitute relining. All relining should be followed by rebalancing the occlusions.

The main advantage to be gained by the use of the quick or self-curing acrylic resin for the relining technique is that it can usually be done in a single sitting of about an hour's duration and prevents the need of depriving the patient of the denture. However, while the other method might force the patient to to go without his denture a day or two while the denture is relined or duplicated, it is possible to obtain more satisfactory results when these procedures are employed.

Even in emergencies in which the cold cure technique can be used effectively, it is possible to reline the dentures temporarily with either an impression paste or a modeling compound and allow the denture to be worn for as long as a week or two, after which it can again be relined and then duplicated.

Regardless of which method may be preferred, there is still another advantage that will accrue to the patient in having the immediate denture relined and duplicated, especially if, in its construction, particular care had been exercised to meet the esthetic and functional requirements fully. Because it requires much less time than the making of an entirely new denture, it is possible to save the patient considerable expense. This is an item that also deserves some of our consideration, and such action is not only appreciated by the patient but may often turn out to be a real practice builder. It is granted that even the best of immediate dentures will eventually have to be replaced, yet if we can prolong their service life, by proper care and attention, this will surely not be looked upon as unethical.

We have long since refrained from speaking of dentures as being permanent, but a sad commentary is that all too many so-called immediate dentures that are being made are, to say the least, entirely too temporary.

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# PRE-EXTRACTION RECORDS TO AVOID PREMATURE AGING OF THE DENTURE PATIENT

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THE DUPLICATION of the basic position of the patient's natural dentition is an important factor in preventing failures of complete dentures and avoiding the unnecessary aged appearance of the patient. Many pre-extraction records have been recommended for retaining these positions. The greater number of these records available to the dentist, the greater is the chance for success.

The use of vertical and horizontal overlap measurements of the natural anterior teeth, and the use of the speaking method and the tattoo dot method to measure and control the vertical dimension have been found to be the most helpful of pre-extraction records. These methods will eliminate the guesswork in jaw and anterior teeth relationships. These procedures are the missing links in the successful building of complete dentures as well as of partial dentures involving the anterior teeth. They help to prevent such common occurrences as inflamed mucous membranes, painful areas, atrophy of the alveolar ridges, and unnecessary movement of the dentures in their intermaxillary relationships. An improved esthetic effect will result in which the patient, instead of appearing and sounding older when the dentures are inserted, will retain his normal appearance and speech character.

## RELATIONSHIP OF ANTERIOR TEETH

It is generally customary for the dentist and the laboratory technician to set the anterior teeth with little or no vertical overlap. If such a relationship is attempted for a patient having a deep natural vertical overlap, one of two things must be done. In order to retain the same appearance of the upper anterior teeth with this reduction of vertical overlap, the vertical dimension must be increased. This is contraindicated,[1] as the patient will not be able to wear the dentures, or the sore spots will ultimately cause a shrinkage of the alveolar ridges, or the wear of the teeth will restore the original vertical dimension. If the normal vertical dimension is maintained, the upper anterior teeth must be placed on a higher plane or the lower teeth must be placed on a lower plane, making the teeth less visible. This change adds age to the patient's appearance and interferes with speech.

Swenson[2] explains, diagrammatically, the importance of placing the arches of the artificial anterior teeth in the proper anteroposterior position. Failure to

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do so causes an abnormal relationship of the teeth to the lip muscles, with a resultant abnormal appearance. Pound[3] states, "The first principle of esthetics is replacing the teeth in the natural position from which they came." Kurth[4] has shown that the protrusive movement of the mandible is not used during mastication. Burgess[5] does not believe in the theory of incisal guidance, and states that the primary controlling factor in mandibular movements is the directional pull of the muscles, and *not* the function of the anterior teeth. The research of Jankelson, Hoffman, and Hendron[6] supports this belief and they state that "there was no evidence that balance of teeth in eccentric positions is a physiologic necessity, or that lack of eccentric balance is less conducive to masticatory function." This scientific and practical facts, as well as personal experience, indicate that it is possible to reproduce even the most extreme vertical and horizontal overlaps of the natural dentition.

The satisfactory reproduction of the patient's natural vertical and horizontal overlaps is dependent on reproducing the natural vertical dimension with the exactness of methods[7, 8] which are to be discussed, and the use of an intraoral central bearing device, such as the Coble balancer.[9] Such a device is used after the completion and insertion of the dentures. It aids in the removal of all premature occlusal contacts and allows for the functional clearance of all occluding teeth. When the occlusion is such as to allow both the upper and lower denture bases to rest solidly on their respective areas, the dentures will be satisfactory during normal dynamic chewing functions.

The reproduction of the patient's natural vertical and horizontal overlaps in artificial dentures is controversial and contrary to present-day teachings. Nevertheless, because of new methods of measuring vertical dimension, experience has shown that this procedure is satisfactory. If it is found necessary to deviate from this procedure for extreme esthetic reasons, the patient should be so informed, and the responsibility regarding the changes in appearance and phonetics should be placed on the patient.

## PHONETIC CONSIDERATION

The teachers of the deaf, such as Dr. Alexander Graham Bell,[10] and his father, Professor Alexander Melville Bell,[11] Yale,[12] and others, have taught the importance of a proper relationship between the teeth and other organs of speech, in order to emit proper sounds. West, Kennedy, and Carr[13] write of the irregularities of the teeth and jaws as a common cause of articulatory speech disorders. Therefore, a deformity of a patient's articulation should not be caused by arbitrarily changing the normal relationship of the anterior teeth. Such a change, in any patient, usually affects the formation of sounds so that they differ from those made previously with the natural dentition.

The normal *th* sound is made with the tip of the tongue resting lightly against the *lingual surfaces* of the upper anterior teeth *at the incisal edges* (Fig. 1). The tongue should normally not protrude between the teeth in sounding the *th*.

The abnormal *th* is made when the tongue is protruded between the incisal edges of the upper and lower teeth (Fig. 2). The sound may be the same as when

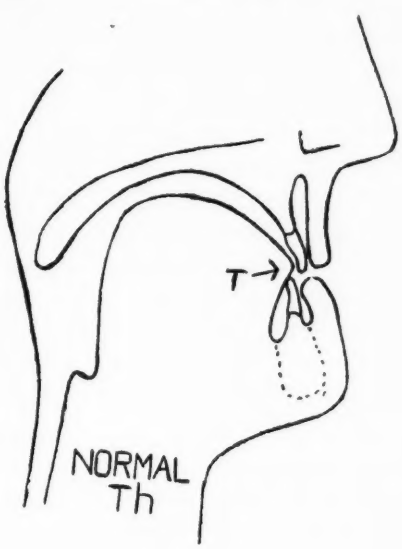


Fig. 1.

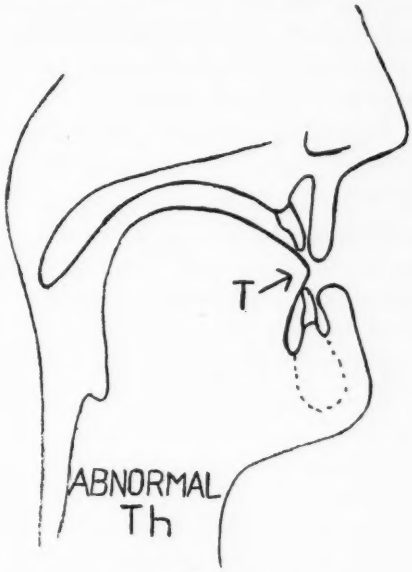


Fig. 2.

Fig. 1.—In sounding the *th*, the tip of the tongue (*T*) rests lightly against the lingual surfaces of the upper teeth at the incisal edges.

Fig. 2.—An abnormal *th* sound is made because of the abnormal position of anterior teeth. If the upper anterior teeth are set too high, or too far back, the tip of the tongue (*T*) may be too low in relation to the upper incisal edges and may slip between the upper and lower incisal edges. The tongue should not protrude beyond the teeth.

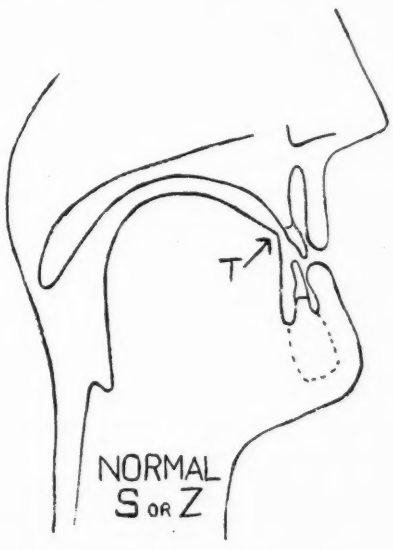


Fig. 3.

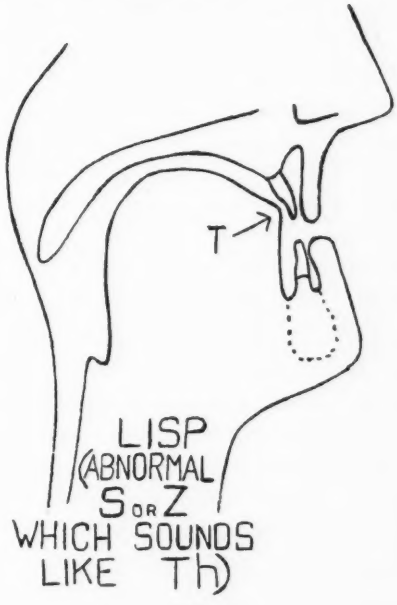


Fig. 4.

Fig. 3.—Note the high position of the tip of the tongue (*T*) in relation to the upper incisal edges in forming the phonetic sound *s* and *z*.

Fig. 4.—A lisp is a resultant *th* sound when the patient attempts to pronounce the *s* or *z*. It may be due to an incorrect position of the anterior teeth. If the upper anterior teeth are set too high and too far back, the tip of the tongue (*T*) will rest at the lingual surfaces of the upper incisal edges and form a *th* sound or lisp.

it is formed normally, but the abnormal protrusion of the tongue is clinical evidence that the upper incisal edges are placed either too high or too far posteriorly, or both.

The normal *s* and *z* sounds are made with the tip of the tongue in a *high position* in relation to the incisal edges of the upper teeth (Fig. 3). There is a small center aperture between it and the anterior part of the hard palate. Through this aperture the breath passes out and strikes against the incisal edges of the upper teeth to form the *s* and *z* sounds. The only difference between these two sounds is that the breath is vocalized in sounding the *z* sound.

The abnormal *s* and *z* sounds usually result in a lisp or the sound of *th* when the anterior teeth are improperly placed (Fig. 4). If the upper anterior teeth are arbitrarily placed too high and too far posteriorly, the tip of the tongue will then rest in a *low position* in relation to the upper incisal edges and may practically touch the lingual surfaces at the upper incisal edges to form a *th* sound or lisp. This malposition of the upper anterior teeth can be caused also by the shifting of the bases due to alveolar resorption and must be corrected in subsequent dentures.

If an imperfection of speech, such as the lisp, is noted, the patient will sound like an older person, like the so-called old-fashioned complete denture wearer, or may even sound juvenile, causing sounds similar to the child's sibilants when he is just learning to speak. This change in phonetics is noted immediately upon the insertion of dentures which do not have proper vertical and horizontal overlaps. It is advisable to avoid raising the level of the incisal edges of the upper anterior teeth, as well as placing them too far posteriorly, to prevent this phonetic problem as well as the esthetic changes. If the lower incisal edges are dropped on their horizontal perspective, the relationship between the tip of the tongue and the lower anterior teeth is changed. This latter relationship should remain normal in order that various sounds may be properly pronounced.

In the event that the teeth or the bases move during the construction of dentures, it may be necessary to grind the teeth to achieve a balanced occlusion. Upon mounting the intraoral central bearing device to eliminate occlusal and incisal prematurities, it may be found that the anterior teeth are touching first. If a considerable amount of grinding is necessary on either upper or lower incisal edges, it is advisable to cut the lower rather than the upper incisal edges, because the esthetics and phonetics will be changed to a lesser degree. The upper teeth must be in the normal position in the arch, because they affect the mechanism of speech more than do the lower teeth. This is apparent when a patient speaks with only the upper denture in place as compared to his quality of speech with only the lower denture in place. In studies of the mechanism of speech, it is noted that most of the sounds are produced by the relationship of the active tongue to the passive upper anterior teeth and palate.[12]

The mouth opens and closes in varying degrees during speech, depending upon which of the approximately 44 phonetic sounds is being pronounced. The various sounds require the mandible to be on certain levels in relation to the maxilla. The production of some sounds requires the mouth to be open wider, others require the mouth to be almost closed, and still others require it to be at various intermediate levels. When phonetic sounds require a wider space

between the mandible and maxilla, there is generally a space between the incisal edges of the upper and lower anterior teeth. This space is called the interincisal space (Fig. 5). In every normal dentition, several sounds cause the obliteration of the interincisal space. There is at least a zero vertical overlap relationship or an edge-to-edge relationship,[14] and often an actual vertical overlap during the closest level of speech.

When building complete dentures where there are no pre-extraction records, it is the author's rule to *create a vertical overlap at least equal to the closest speaking space.* In many patients, the vertical overlap is greater than the closest speaking space. By following this rule, an interincisal space between the upper and lower incisal edges, with a resulting lisp, can be avoided when the mandible is on its closest speaking level in relation to the maxilla.

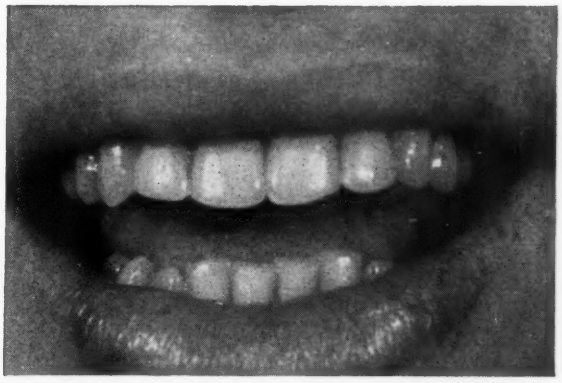

Fig. 5.—The interincisal space exists between the upper incisal edges and the lower incisal edges during speech. This space should generally be obliterated when the mandible is at its closest level in relation to the maxilla during speech.

## MEASURING THE RELATIONSHIP OF ANTERIOR TEETH

The relationship of the anterior teeth of the natural dentition should be measured and recorded. This is done *before* the removal of any of the posterior teeth to be certain that these measurements are made with the jaws in their normal vertical relationship. If partial dentures are worn, the measurements should be made with them in place. In our office, the patient's card is stamped with a rubber stamp (Fig. 6) which provides places for the necessary information, such as the measurements of the vertical and horizontal overlaps, the closest speaking space both by use of individual words and when reading rapidly, and the amount of forward movement of the mandible during speech. Records of dates of periodic measurements furnish information as to when there may be changes in the relationships of the jaws and teeth.

## VERTICAL AND HORIZONTAL OVERLAPS

The vertical overlap is measured by having the patient close into centric occlusion, and, with a sharp pencil, drawing the centric occlusion line (Fig. 7)

.....19.....

Vertical Overlap:

Horizontal Overlap:

Closest Speaking Space: < Words: / Reading:

Mandible Forward?:

Fig. 6.—The chart for recording various measurements on the patient's record. It is placed on the record by means of a rubber stamp. It is advisable to reproduce the same measurements as found in the natural dentition in subsequent complete dentures.

Fig. 7.

Fig. 8.

Fig. 9

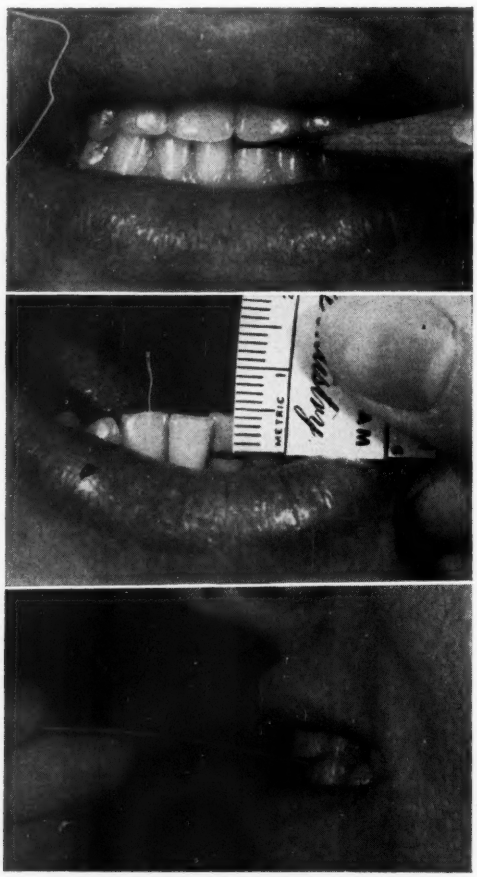

Fig. 7.—The centric occlusion line is drawn on the lower anterior tooth at the horizontal level of the opposing incisal edge, while upper and lower teeth are closed in centric occlusion.

Fig. 8.—Measuring the vertical overlap which is the distance from the centric occlusion line to the incisal edge of the lower anterior tooth.

Fig. 9.—Measuring the horizontal overlap which is the distance from the labial surface of the lower to the labial surface of the upper teeth. This is done while the upper and lower teeth are in centric occlusion.

on a lower anterior tooth at the horizontal level of the incisal edge of the opposing upper anterior tooth. The vertical overlap (Fig. 8) is the distance from this centric occlusion line to the incisal edge of the lower anterior tooth.

The horizontal overlap is determined by having the patient close into centric occlusion and then measuring the distance from the labial surface of the lower tooth to the labial surface of the upper tooth with a millimeter rule (Fig. 9).

If the vertical and horizontal overlaps of the anterior teeth are recorded and reproduced in complete dentures, the patient's natural vertical dimension must be reproduced *exactly*. This helps to maintain the patient's esthetics and phonetics. If there is any deviation in the levels of the natural vertical dimension, the patient generally does not feel, look, or sound the same, even if the natural relationship of the anterior teeth is duplicated.

## FORWARD MOVEMENT OF THE MANDIBLE

The forward movement of the mandible while speaking[14] is recorded in millimeters. It was found that in 55 per cent of the patients surveyed the mandible moved forward in varying degrees.[15] Because of this movement while speaking, it is most important for mechanical, esthetic, and phonetic reasons that the horizontal overlaps be reproduced in the anterior teeth. It is advisable to observe the patient while he is reading aloud or speaking rapidly. If, for example, the mandible moves forward to an edge-to-edge relationship during speech, and it is known that there is a 3 mm. horizontal overlap, then the forward movement of the mandible is 3 mm. If the mandible moves forward only part of its horizontal overlap, it is possible to measure this forward movement in a similar manner as the horizontal overlap is measured. (See Fig. 9.) Sometimes it is easy to observe the mandible in a forward position with individual words requiring a phonetic sound such as *s* in ye*s*. If the patient should control the mandible voluntarily, the mandible will not reach a normal forward position. When the patient reads aloud, all conscious effort at control is abolished, and the mandible moves forward naturally. When the patient does this, the patient may be able to repeat the word which causes the forward movement so the measurement can be made. If the measurement cannot be made in this manner, it will be necessary to approximate the measurement by sight. *The forward movement is never beyond an edge-to-edge relationship,* except in patients with a Class III malocclusion and in patients who have had improper orthodontic treatment.

The vertical and horizontal overlaps of the incisor teeth should be measured and recorded also at the time of the insertion of the dentures, and for several weeks thereafter, and then at intervals of six months. Should there be changes in jaw relationship, the cause and the extent should be determined, and the corrections made in subsequent dentures.

## MEASURING VERTICAL DIMENSION

The speaking method[7] is the most accurate, scientific, and practical means of measuring vertical dimension. This measurement should be recorded *before* the remaining natural teeth are removed and it must be reproduced in complete

dentures when they are made. When this measurement is made with the natural dentition intact, the guesswork is removed from determining the patient's natural vertical dimension.

To measure vertical dimension, the centric occlusion line (Fig. 7) is drawn on a lower incisor at the horizontal level of the opposing upper incisal edge when the patient closes into centric occlusion. The closest speaking line (Fig. 10) is then drawn on the same lower incisor while the patient pronounces the sound *s* of yes. Also any of the other sibilants, like *sh* of fi*sh*, *z* of bu*zz*, *zh* of measure, *ch* of *ch*ur*ch*, and *j* of *j*udge can be used. Often, all of these sounds will place the mandible on its closest relation to the maxilla. If only one or a few of the sounds place the mandible on the closest level in relation to the maxilla, a record is made of the sounds with their respective distances in millimeters. The distance from the centric occlusion (bottom) line to the closest speaking (upper) line is the *closest speaking space*. This space is the measurement for vertical dimension, and should be recorded in millimeters. The closest speaking space has been found to be constant in tests conducted since February, 1950, and it is felt that it should be constant throughout life. Records are being kept to test this hypothesis. The closest speaking space of natural dentitions *must* be reproduced in complete dentures at a later date.

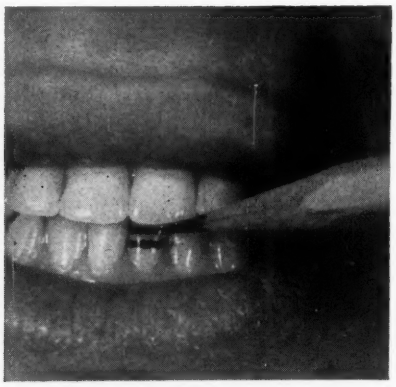

Fig. 10.—The closest speaking line is drawn on a lower anterior tooth during the sounding of the phonetic sound *s* of yes. The distance from the centric occlusion (lower) line to the closest speaking (upper) line is the closest speaking space. This space is the phonetic measurement for vertical dimension. If the closest speaking line is at the same level as the upper incisal edge while the *s* sounds are pronounced during rapid speech, it is certain that an accurate measurement of the vertical dimension has been obtained.

The closest speaking line is first drawn by the use of individual words containing any of the six sibilants, preferably at the end of a word. The phonetic sound *s* of ye*s* and mi*ss* (after pronouncing Mississippi several times and then cutting it short) can be used to mark the closest speaking line. The sound *s* is the sibilant most frequently used[16] and can be used conveniently and exclusively to draw the closest speaking line. After this line is drawn, it is imperative that the patient be watched during rapid speech or while he is reading aloud rapidly. If the upper incisal edge coincides with the upper closest speaking line while pronouncing the *s* sound, it is assured that the vertical dimension as measured

with individual words is correct. A patient may control the jaw while an individual word is used to draw the upper closest speaking line. It is *impossible* to control the mandible while the patient speaks normally or reads rapidly because all conscious muscular control is lost. If a patient laughs during speech, he uses muscular control, and produces an incorrect measurement.

The measurement of the closest speaking space is easily accomplished with repeated accuracy. In exceptional cases it might be difficult, and any deviations from normal should be noted on the patient's record, because the same difficulty is generally present with accurately built complete dentures as is found with the natural dentition.

The measurement of vertical dimension by the use of the speaking method with its closest speaking space should not be confused with the rest position of the mandible or the free-way space. The closest speaking space measures vertical dimension when the mandible and the muscles involved are in phonetic *activity,* while the free-way space measures vertical dimension when the mandible and muscles involved are at complete *rest.* Although the measurements for the closest speaking space and the free-way space in the same patient are different, they may be the same coincidentally. The measurement of vertical dimension by the free-way space may require hours of measuring and rechecking. It is almost completely dependent on the patient's ability to relax and cooperate, and at times it might be necessary to prescribe barbiturates to achieve this relaxation. It is not only difficult but can be inaccurate. Measurement of vertical dimension by the closest speaking space requires only a minute or even seconds to measure and recheck, and is not dependent on the patient's cooperation. The patient gives us the measurements easily and involuntarily.

The closest speaking space of the teeth set up in wax should be the same as that recorded from the natural dentition. If the closest speaking space of the trial dentures is less than that of the pre-extraction records, it is due to the vertical dimension being increased beyond normal. If the closest speaking space of the wax setup is greater than that of the pre-extraction records, the vertical dimension is decreased beyond normal. These deviations of the trial dentures from the natural dentition must be corrected before the dentures are processed.

In making immediate dentures, the natural vertical dimension can be reproduced automatically, providing that all steps of the complete denture procedure are accurately followed. If there are any discrepancies in the vertical dimension as well as the vertical and horizontal overlaps of the finished dentures, their cause and extent should be determined by referring to the pre-extraction records, and corrections made accordingly.

### TATTOO DOTS ON THE MUCOUS MEMBRANE

Tattoo dots[8] also are used as pre-extraction records. If a waiting period for the healing of the alveolar ridges is desired, tattoo dots are placed on the mucous membrane of the alveolar ridges prior to the removal of the natural teeth.

The tattoo dots are placed with a Luer Lok syringe and needle containing a small amount of waterproof drawing ink (India ink) or Chinese indelible laundry ink. The needle is inserted into the hard tissue between the roots of

the teeth, and then twisted slightly to insure the deposition of some dye. Care must be taken to avoid depositing too much ink into the tissues. The syringe is held by the barrel, and the plunger should not be touched. This will produce a small accurate dot. If there is insufficient ink, or if the dots are placed in highly vascular tissue, they may disappear in time. The dots must not be placed in the movable tissues at the base of the alveolar ridges. This tissue is highly vascular, and a small accurate dot may not be obtained. The dots can be placed almost painlessly with a sharp beveled needle. A topical anesthetic or Novocain may be used, although it is not necessary.

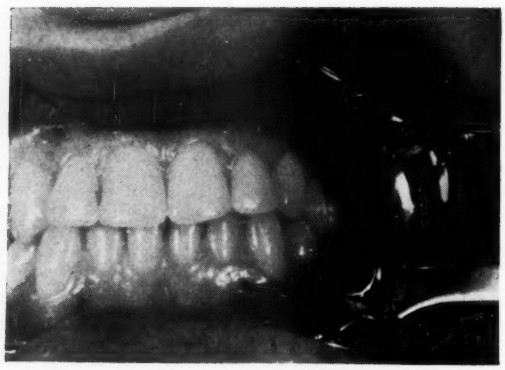

Fig. 11.—The caliper measurement between the tattoo dots is made when the teeth are in centric occlusion and included in the pre-extraction records. The measurement is reproduced when dentures are made. Note the dots on the opposite side of the mouth.

Dots are placed in the mucous membrane of both arches in the vicinity of the lateral incisors or cuspids, on both sides of the mouth. The distance between the dots when the teeth are closed in centric occlusion is measured with a pair of calipers (Fig. 11) and recorded for future use. These measurements should be rechecked several days later, to be certain the dots did not move due to the diffusion of the dye. If there should be a difference in the measurements between the dots, corrections of the patient's record should be made. If dye diffusion causes the dot to enlarge, the exact spot of the needle puncture can often be seen under a magnifying lens. When this spot is located, the measurements can be made with accuracy. After the healing period, and during the establishment of the maxillomandibular relationship of the dentures, the distance between the dots should be the same as that recorded when the natural teeth were in centric occlusion.

If the tattoo dots disappear or move due to surgery or the healing process, the vertical dimension can be established or corrected by referring to the closest speaking space as recorded in the pre-extraction records. The comparison with the closest speaking space records should be made at the time of the try-in of the teeth.

## SUMMARY

1. The vertical and horizontal overlaps of the anterior teeth of the natural dentition should be reproduced as closely as possible in complete dentures. This

duplication maintains the same esthetics and phonetics as found with the natural dentition and prevents the patient from appearing and sounding older than he should. Those overlaps should be recorded prior to the removal of the remaining natural teeth. The reproduction of these overlaps is dependent upon the establishment of vertical dimension with accuracy, and upon the elimination of all occlusal interferences.

2. A great number of speech sounds are made by the articulation of the tongue with the upper anterior teeth. This normal relationship should not be changed. If it is necessary to grind the anterior teeth, due to premature contact, it is the lesser of the two evils to grind the lower teeth. This will have less effect on the phonetics and the esthetics than to shorten the upper teeth.

3. In normal dentitions, there should *NOT* be an interincisal space between the upper and lower incisal edges when the mandible is at its closest speaking level in relation to the maxilla. If there should be an interincisal space, the phonetics as well as esthetics are affected. This causes unnatural sounds, such as the lisp, or a difference in the normal speech which makes the patient sound like an older person, or at times, juvenile. If old dentures show an interincisal space while the mandible is at its closest level to the maxilla during speech, corrections in new dentures should be made. Assuming that the vertical dimension is accurate, the *vertical overlap of the new dentures must be at least equal to the closest speaking space found in the old dentures,* and in some cases the vertical overlap is greater than the closest speaking space. This will eliminate any interincisal space while the mandible is at its closest level to the maxilla during speech.

4. The most forward position of the mandible during speech should be recorded.

5. In normal cases, the forward movement of the mandible during speech is never beyond an edge-to-edge relationship.

6. The vertical dimension of the natural dentition should be recorded by the closest speaking space for reference and control in the building of complete dentures. This is a physiologic means for measuring vertical dimension while the mandible, with its controlling muscles, is in phonetic *activity.* The closest speaking space is different from the free-way space which measures the vertical dimension when the mandible and the muscles involved are at complete *rest.*

7. Tattoo dots on the alveolar ridges are reference points for transferring the same vertical dimension from the natural dentition to complete dentures.

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# MASTICATORY EFFICIENCY DURING THE PERIOD OF ADJUSTMENT TO DENTURES

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IT IS GENERALLY recognized that most denture patients require several weeks to become accustomed to complete upper and lower dentures. During the period of adjustment, the patients either may learn to achieve greater masticatory efficiency or may find how to tolerate whatever masticatory handicaps they may possess. Our studies in this laboratory have shown that there is a considerable variation in masticatory function of denture wearers,[1-8] but the changes in function from the day of insertion through the period of adjustment have not been evaluated.

The general purpose of this investigation was to study the change in masticatory efficiency as patients became accustomed to dentures, and to probe into the questions of whether denture stability, the age of the patient, or previous experience with one or two complete dentures are influential in helping the patient during his period of adjustment.

## EXPERIMENTAL PROCEDURE

Seventy-four patients presenting for complete dentures were examined, and thirty-eight were accepted for this study. The selection was made to obtain patients who were judged to be normal from the standpoint of denture construction, freedom from anatomic, pathologic, or functional abnormalities and from obvious mental incapacities. Thirteen of the patients received dentures constructed by graduate dentists under the supervision of Dr. I. R. Hardy, twenty patients received dentures constructed by students in the Prosthetics Department, Tufts College Dental School, and five patients received dentures constructed by one of the authors (P. V.). Six patients were 25 to 40 years of age, sixteen were 40 to 60 years of age, and sixteen were 60 years of age or over, representing a fairly normal age distribution for complete denture service. Sixteen patients received their first complete dentures replacing natural dentitions, twelve obtained replacements for an upper denture and lower denture replacing a natural dentition, and ten had replacements made for upper and lower dentures previously in use.

The patients were tested for masticatory function at the time of insertion of the new dentures, the following day, and at periods of approximately one week,

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one month, and six months later. Prior to each test the mucosa was examined for clinical signs of irritation, and the dentures were adjusted as needed. The maximum biting force was recorded for each subject using a Howell-Manly oral force meter,[4] and two masticatory function measurements were obtained on each subject. Masticatory performance tests were carried out by the Yurkstas-Manly method[5] and converted to masticatory efficiency according to a table.[6] A second test allowed the patient to chew quantities of the test food selected by him until the food was ready for swallowing. At this point the food was expectorated, and its degree of pulverization was measured with a 10 mesh screen. The unrestricted chewing test provided information on the degree of pulverization at swallowing. This degree of pulverization represents the minimum pulverization which the patient will tolerate in swallowing and the number of strokes he requires to obtain this result.

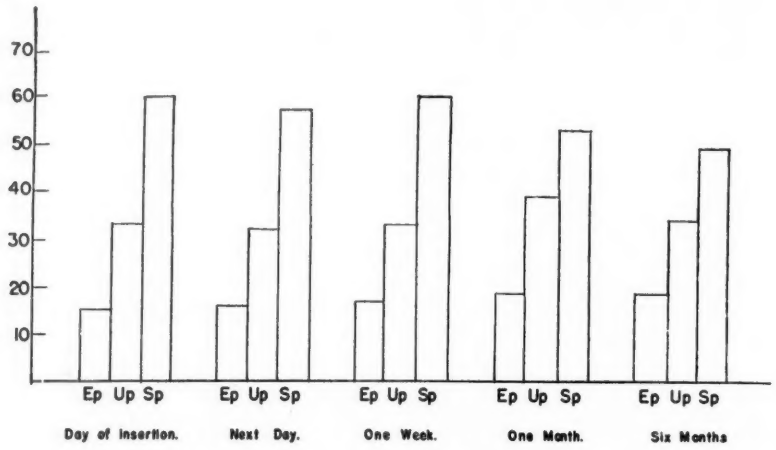


Fig. 1.—Masticatory function over a six-month period by 38 complete denture patients. Ep, refers to the mean of the calculated masticatory efficiencies, Up, to the mean pulverization of peanuts when the patient considered the food ready for swallowing, and Sp, the number of masticatory strokes needed by the patient to attain this degree of pulverization. Pulverization is measured as the percent of food capable of passing a 10 mesh screen.

The average change of masticatory efficiency over the six-month period is summarized in Fig. 1 in which the mean efficiencies are plotted for the different periods after insertion of the dentures. It appears that the efficiency of the group as a whole does not change appreciably since it changes only from 15 to 19 per cent. Here the base (or 100 per cent) is the efficiency of a group of 50 dental students who had at least four natural occluding teeth—2 pairs each of premolars and molars. Nineteen per cent is only slightly lower than the mean of a group of 100 denture wearers which the authors studied previously.[2] The food pulverization at the swallowing point did not change for the group. Thirty-three per cent of the food recovered during the first test period passed through a 10 mesh screen. There is no indication of a tendency to swallow larger particles of food as the patient becomes accustomed to his denture. The mean number of masticatory strokes, however, decreased from 60 just after the dentures were inserted to 49 strokes at the end of six months. The slight increase in efficiency may have been utilized by the

patients to permit them to use less effort in pulverizing their food. The general conclusion to be drawn is that efficiency increases little if any during a six-month period for the group as a whole, and that whatever improvement there is does not result in better preparation of the food—merely less effort on the part of the patient.

Each patient actually believed that an improvement in chewing ability had been achieved over the six-month period. The measurements failed to substantiate this opinion, and perhaps the patients' impressions mean that they learned how to manipulate food with comfort and to tolerate the physical mass of the dentures.

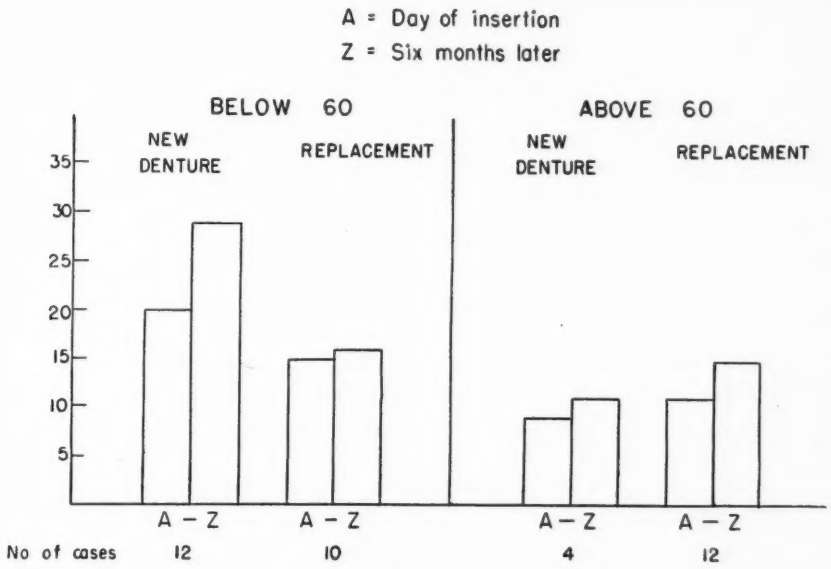


Fig. 2.—Efficiency by age group and type of denture service.

It seemed possible that young patients receiving dentures for the first time would be more likely to show an improvement during the adjustment period, whereas older patients, especially those who had made one adjustment to dentures previously, would be less likely to better their efficiency. The assumption was correct. In Fig. 2 the findings on efficiency are grouped according to age of the patient, whether below or above 60 years of age, and according to whether or not wearing of complete dentures was a new experience to the patient. Those persons below 60 who received new dentures for the first time had an initial efficiency of 20 per cent which increased in six months to 29 per cent. The difference is not statistically significant but could become significant if more patients had been studied. In contrast, all other groups showed little or no change in efficiency. This finding suggests that improvement in chewing efficiency may occur for those patients who receive complete upper and lower dentures for the first time, if the patients are below 60 years of age.

In order to evaluate whether denture stability was a factor that could affect denture manipulation, patients were selected in pairs according to age, sex, and type of denture service. One patient of each pair received a commercial denture

powder with instructions for its use, and the other was requested to avoid using denture powder. Fig. 3 presents the mean efficiency of patients above and below 60, subdivided according to denture stabilization. Patients under 60 who had been requested to use denture powder had a higher average efficiency at six months than did the control at the same period. This difference was statistically significant at the 2 per cent level. Patients with stabilization also had greater average improvement in efficiency during the same period than did the control, but the improvement was not statistically significant.

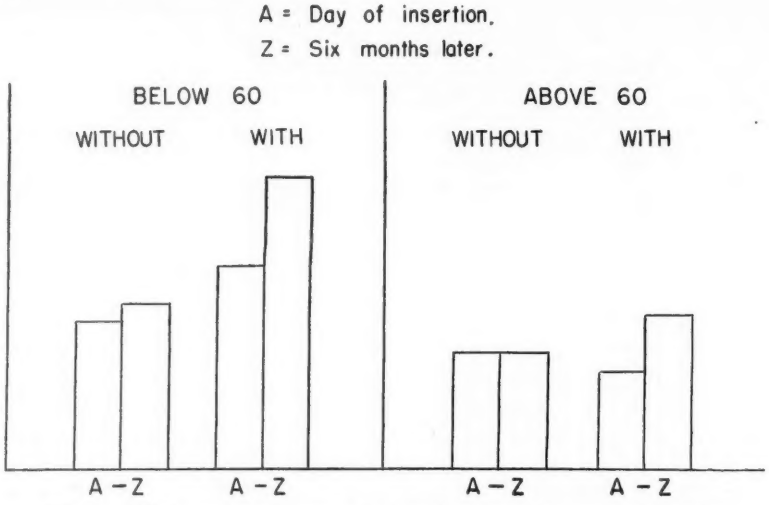


Fig. 3.—Efficiency by age group with and without denture stabilization.

## SUMMARY

Thirty-eight complete denture patients were given masticatory performance tests over a six-month period starting on the day of insertion. For the group as a whole there was no marked change in average masticatory efficiency, in the strokes needed to prepare food for swallowing, and in the particle size of food at the swallowing point. Apparently adjustment to dentures appears to be subjective rather than functional. Findings suggested that patients under 60 years of age who received dentures for the first time, especially if they used denture powder, would be most likely to show improvement in function during the six months following insertion of the dentures.

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# PROSTHETICS AND GERIATRIC NUTRITION

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THE AUTHOR WHO conceived the phrase, "Life begins at forty," would have experienced difficulty in justifying his conclusions had he been a dentist. It has proved practical to assume that the geriatric approach to dentistry becomes applicable at 40 years of age, for it is at this time that the insidious, progressive disorders so significant in later years become manifest. The actual beginnings of important disorders occur far earlier than their signs and symptoms are clinically detectable.

The rise in the proportion of older people in our population has in large measure been due to extension of the average expectancy of life. In 1950, the U. S. Census showed that there were 12,256,000 people past the age of 65. Within twenty-five years it is believed that this segment of the population will increase to over 25,000,000. The rapid advance in life expectancy is seen in the estimate that it was 21 years in the sixteenth century. By the time of the American Revolution it had advanced to 35 years, to 47 years in 1900, and to 63 years in 1940. Further advances are predicted to the age of 75 in forseeable years to come. Predictions that this aging of our population will continue cannot be other than startling to those of us who appreciate the significance of these predictions in relation to medical and dental care of older people.

We know little of the biology of aging. We know that the rate varies among the various tissues of the body. Aging begins at conception, and 99 per cent of the growth potential is expended during intrauterine life. The manifestations of aging are conspicuous and dramatic in infancy and youth; aging change proceeds at an ever-diminishing rate, although the deceleration is not constant. The elderly are not just "old people"; they are structurally, functionally, and mentally different men and women from what they were in the days of their youth and early maturity.

The apparent boon of longevity may become a curse, which is one of the reasons why the need to learn more about the aging process is urgent. Long life without good health is not only an individual personal tragedy, but a social problem of national proportions. That we are fast becoming a nation of old folks cannot be denied. Old age can be wonderful and fruitful, but we must stimulate ourselves to greater efforts of care for the aged and to look upon the old as completely necessary to our civilization. Geriatric medicine and dentistry

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The opinions or assertions contained herein are the private ones of the author and are not to be construed as official or reflecting the views of the Army Dental Corps.

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have the responsibility of enabling the older patient to continue his contributions to our world by appreciating his problems and providing adequate treatment. Specifically, it is the prosthodontist who plays the important role for dentistry in the rehabilitation of the aging individual.

## ROLE OF THE PROSTHODONTIST

Since the prosthodontist works primarily with the middle and older age groups, he is most concerned with the general health and well-being of the older patient. It is a common tendency to become so engrossed with the technical details of denture construction that we lose sight of the patient as a whole. Most of us are familiar with the aging patient with poor mental and physical health for whom no prosthodontist could make a satisfactory denture regardless of his technical ability. Mental and physical health in patients of any age are factors exerting great influence on the successful use of dentures, but many of the debilitating diseases of old age impose a greater challenge to success. We must look to the physician for help in treating chronic glandular dysfunctions, circulatory disturbances, and bone and tissue pathologies, but we can and should concern ourselves with the factor of nutrition in relation to dental dysfunction among older age groups.

Persons who have lost all or some of their teeth, and are using dentures, show wide variation in functional efficiency. Some of them use their prosthetic appliances with great skill while others find similar appliances intolerable. The degree of skill used in constructing a denture determines to a large extent the efficiency of its use. This cannot, however, be regarded as the only criterion for successful dentures. Physicians tell us that more than half of their patients over 50 years of age complain of indigestion, which is due in great part to dental dysfunction and the resulting poor nutritional intake. Loss of natural teeth or a set of poorly fitting dentures are matters of serious concern to most old folks. Difficulty in masticating food properly, which forces the patient to change to a soft or liquid diet, can have serious mental and physical health effects. Nutritional problems may be difficult to handle in older people because eating habits of a lifetime are not easily changed. The older person often rebels against too much restriction or too wide a change from his accustomed foods. The aged are often childish in their likes and dislikes; they may gorge themselves on their favorite dish and refuse to eat enough of the essential foods. They are sometimes forced into adverse food patterns because of social reasons—embarrassment in properly masticating meats, fruits, and vegetables because of poor dentitions or uncomfortable dentures. Thus they tend to seek "softer" foods. This usually results in a serious increase in carbohydrate foods.

## DIET AND NUTRITION

As we grow older all of our body processes tend to slow down, and hence our caloric requirements for general bodily processes continually decrease. The average adult calorie requirements are 10 per cent less when we have reached the age of 60, 20 per cent less at the age of 70, and 25 per cent less over the

age of 90. The reasons for this decreasing calorie requirement are reduced muscular activity and a slower basal metabolic rate. The older patient, therefore, should be advised to curtail the total amount of food in the diet, especially foods of high fuel or caloric value. A fondness for rich foods, a continuance of eating habits formed in more active years, or the increased money spent for food in the more prosperous years of late middle life may result in the excessive consumption of more food than the body can tolerate. Life insurance statistics show that normal life expectancy can be reduced two years for each 10 pounds of excess weight. The obese person is a sick person, and sick people are poor denture patients.

Nutrition is more than just diet. Nutrition includes not only the ingestion of an adequate and balanced diet, but also the digestion, absorption, and transportation to the tissues of essential food elements, and utilization of these elements by the body cells. Nutrition may be seriously impaired at any one or more points in the complex chain of metabolic activity.

For a satisfactory diet, the older person requires more attention to the preparation of his food. The acuteness of our senses decreases as we get older, so that our continued loss of the sense of taste and smell leads us to seek more spirited, highly seasoned, or sweeter foods to compensate for the waning sense of taste. Thus, the older denture patient is led into undesirable nutritional habits. More attention to food preparation and serving will tend to correct these undesirable habits. Regardless of its palatability, food is chewed poorly when the teeth are faulty. This leaves the stomach more work to do, with discomfort and indigestion the inevitable result of this added burden of work.

With the slowing down of the general metabolism in the aging process, there is a decrease in glandular secretions. The salivary glands secrete less, so that there are less mucin and other digestive enzymes present during the inital stages of digestion. Thus, a great deal of the food reaches the stomach *partly* lubricated and digested, which throws more burden on the stomach and intestines. Older people must masticate their food more thoroughly, or purée the food in preparation, so that it is more easily digestible. Furthermore, in the aged, the tonus of the muscles of mastication and deglutition is markedly reduced. As with all other body joints, the temporomandibular articulation also shows the degenerative changes. The prosthodontist who gives some thought to the importance of nutrition can help the older patient make the most of his limited functional resources, and can spare the patient many of the consequences of nutritive and masticatory deficiencies.

## IMPORTANCE OF VITAMINS

The importance of an increased vitamin intake for the geriatric patient cannot be overemphasized. As a group of body regulators, the vitamins function in the maintenance of health and vigor by aiding digestive efficiency, especially the utilization of mineral elements and the oxidation of carbohydrates. The vitamins contribute to nervous stability and more effective resistance to bacterial infection by promoting the growth of healthy tissue. It should be pointed out that when several vitamins participate in promoting some function of the body,

lack of any one of them will suffice to inhibit this function. In the aged the intake of all of the vitamins should be increased. There is much evidence to warrant a higher intake of specific vitamins for the aged, namely, vitamins A, B complex group, C, and D. Aged groups seem to require vitamin C in large quantity; they seem to feel much better and are able to do more work when vitamin C is added to their diet. Essential vitamins should normally be provided by fruits, green and yellow vegetables, milk, butter, eggs, and whole grain cereals.

## MINERALS

Defective mineral metabolism causes lowered resistance to certain diseases, and this applies particularly to diets low in calcium. Calcium deficiency in youth and adult life probably plays a capital part in the conditioning process preceding senescence. Many diseases of later life can be attributed to calcium—vitamin D starvation in adult life, especially in cases of osteomalacia. Gradual demineralization over a period of years, chargeable to calcium deficiency, will cause skeletal changes and pathologies of the kidneys and other organs. Loss of calcium and phosphorus as a result of alimentary disturbances in the aged are factors in the characteristic atrophy of bone seen in senile persons. Among the most common causes of inadequate utilization of ingested calcium are lowered gastric acidity and hepatic and pancreatic insufficiency. These result in a reduced fat absorption, and the inability to absorb the fat-soluble vitamin D essential for the utilization of ingested calcium. The calcium balance in the diet of the aged is extremely difficult to maintain, since an excessive calcium intake is not advisable. The phosphorus requirements are 1.32 Gm. daily in advancing years, and the iron allowance should be from 12 to 15 mg. daily. A mild anemia is often found in the aged patient, due to a deficiency of iron in the diet. To prevent this, foods rich in iron such as lean meats, liver, eggs, leafy vegetables, molasses, raisins, peaches, and whole wheat should be included in the diet. These foods are particularly desirable because they also contain copper, manganese, and cobalt—minerals that enhance the synthesis of iron into hemoglobin. Iodine and the many other minerals must be kept in adequate supply. Milk, green vegetables, and fruits are especially rich in mineral elements.

## PROTEINS

If we omit the water content of the body, a person of average build is almost entirely protein. Only 4 per cent of the body consists of inorganic materials, chiefly calcium. The principal carbohydrate is glycogen, with about eight ounces of it stored in the liver and muscles. Fats are a variable item, but can be less than 1 per cent of body weight with no evidence of diminished health function. The body can build fat from carbohydrates or proteins. It can build carbohydrates from proteins. However, it can build but little protein from either fats or carbohydrates. Proteins can be built only from protein fragments, the amino acids. Blood cells are chiefly protein, and plasma is a protein suspension. Among the activators, most enzymes are protein, as are many of the essential vitamins such as thiamine, riboflavin, niacin, and para-aminobenzoic acid. The hormones, insulin,

thyroglobin, and all of the recognized hormones of the anterior pituitary gland are proteins.

We are not only made up of proteins, but we are also operated by them. New discoveries show how quickly the body functions are distracted from their normal activity when good quality proteins are omitted from the diet. The disturbances are evident within one day, and become severe within a few days. Quality in a protein food is determined by its content of essential amino acids. Meats, eggs, milk, and cheese are principal sources of useful protein. In the aged, the tendency to a higher carbohydrate and lesser protein intake must be reversed. The body can get along better with fewer fats and carbohydrates as old age is approached, but it cannot survive long in health with a loss of the essential proteins. Dental dysfunction has been a prime cause of this shift to softer foods. Many diseases and general debilitating states are the result of protein insufficiency. In nephritis, and more especially in osteoporosis, a high protein diet may be indicated. The height of the serum protein level may be a large factor in bone formation, since the protein lack, allowing for a negative nitrogen balance, makes it impossible for the osteoblasts to lay down the organic bone matrix.

It is possible to determine, empirically, the amount of food needed by an aged person if one eliminates any food ingestion which results in a sensation of heaviness after meals. A good digestion is to be assumed if the patient is hardly conscious of having eaten. The aged person must limit himself to essential foods, and moderation in eating and drinking is essential to good health. An increased water intake for the aged is important. Water is an essential food element, serving as a medium for metabolic reaction, regulating temperature, acting as a lubricant, removing waste, and serving as a building material in the supply of minerals.

Nutrition is but one of the many factors which determine success or failure of prosthetic appliances in the mouths of aging people. The prosthodontist should not be unaware, however, that a well-balanced diet of essential nutrients is vitally essential to the general health of his patient and to the success of his dentures. Whether or not poor nutrition is the cause of denture trouble, the results are the same—poor health and an unhappy patient. It is a peculiar hazard of the specialist that it is too easy to know a lot about a little. The true specialist in any field of dentistry, including prosthodontics, never loses the concept of total health of his patient. The food intake that is best for dental health also satisfies the needs of all the body tissues. There can be no diet for dental health that is not a diet for total health.

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# THE MOVEMENTS OF THE TEMPOROMANDIBULAR JOINT AND THEIR RELATION TO THE PROBLEMS OF OCCLUSION

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TEMPOROMANDIBULAR MOVEMENT is but one of the factors in the study of occlusion. We are concerned also with the prominence of the compensating curve, the height of the cusps, the inclination of the incisal guidance, and the orientation of the plane of occlusion.[1]

The movements of the temporomandibular joint are the factors over which we have no control in our problems of occlusion. The most we can do is give them full consideration in our attempts to modify or build occlusal schemes.

Physiologically, occlusion may be divided into two phases: dynamic or functional occlusion, and static or nonfunctional occlusion. Each phase is extremely important, and one should not be given full preference at the expense of the other. The movements of the temporomandibular joint are important in both dynamic and static occlusions.

To understand the movements of the temporomandibular joint, it is necessary to understand a little about its anatomy and physiology, and to associate this knowledge with some of the processes in physics. In occlusion we are dealing with a complicated system of inclines and spheres, moving around multiple, slightly displacable centers of rotation. An occlusal problem is a problem in biophysics with temporomandibular movements as the fixed factor.

The temporomandibular joint is formed by the articulation of the mandibular condyle with the articular fossa and the articular eminence of the temporal bone. The articular fossa is an oval-shaped fossa about three-quarters of an inch wide mediolaterally, and an inch long anteroposteriorly. The condyle, which may vary in shape, is also about three-quarters of an inch wide. This allows it to fill the fossa mesiolaterally. Its long axis is directed inward and backward to such a degree that if it were extended, it would bisect the axis of the opposite condyle in the region of the foramen magnum. Anteroposteriorly the condyle is approximately one-half inch in diameter. In this dimension it occupies about one-half of the fossa, the anterior half.

The joint cavity is divided into an upper and lower compartment by an interarticular disc of dense fibrous connective tissue.

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The function of any ligament is to limit the movement of a joint. The joints are held in position not by the ligaments, but by some or all of the muscles responsible for their movement.

There are two ligaments which meet these requirements in the temporomandibular joint. They are the capsular and the temporomandibular ligaments. The stylomandibular and sphenomandibular ligaments appear to have no function in relation to the joint.

The capsular ligament is a loose sack which is attached to the glenoid fossa, the margin of the articular disc, and the neck of the condyle. It is penetrated in front by the tendon of the superior head of the external pterygoid muscle, which is attached to the articular disc.

The articular disc is an oval plate of dense fibrous connective tissue interposed between the two articular surfaces.

The temporomandibular ligament is a triangular band of ligamentous tissue that is added to the lateral part of the capsular ligament. It is attached to the lower border of the zygoma and the tubercle at the root of the zygoma. It is directed downward and backward to be inserted into the lateral surface of the neck of the condyle.[2] The direction of its fibers indicates that it limits the backward movement of the condyle.

The lower portion of the joint is a ginglymus or hinge type of joint while the upper portion is an arthrodial or gliding type of joint, and this is what makes the understanding and recording of its movements rather complicated. We have a hinge or rotational center that can be moved to any position on a resilient, irregular, somewhat spherical incline, the articular eminence. This movement is brought about by the contraction of a series of muscles of different power potentials and different angles of pull, so that the final movement is the resultant of a number of factors.

Of the *closing* muscles of the mandible the temporal is the strongest, the masseter is next, and the internal pterygoid is third;[3] however, they do not all pull in the same direction. We can represent the pull of these muscles and their resultant force by a parallelogram of forces. The internal pterygoids and the superficial fibers of the masseter pull forward and upward. The deep fibers of the masseter pull backward and upward as do the posterior fibers of the temporal, while some of the anterior fibers of the temporal pull upward and forward. If we examine Wilson's parallelogram of forces (Fig. 1), we notice that the resultant with full contraction of all the closing muscles is straight up.[4] However, we can contract a part of the fibers of any of these muscles, at will, depending on our neuromuscular skill. For instance, we can retract the mandible by contracting the posterior fibers of the temporal muscle.

To open the mandible, the suprahyoid muscles come into play for the first part of the opening. If we were to examine a roentgenogram of the mouth open, we would see that the hyoid bone remains in place; therefore, it must be stabilized by the infrahyoid muscles while the suprahyoids start the opening movement.

When the mouth is partly open, we can notice in a roentgenogram that the hyoid bone is level with, or above, the insertion of the suprahyoid muscles, so other muscles must take over the opening at this stage, and these muscles are the

external pterygoids. This is of interest to us from the standpoint of occlusion for the following reasons:

First of all, when we are dealing with natural teeth, about 50 per cent of our patients demonstrate changes in the occlusion,[5] because of loss of some of the dentition or because of wear, perhaps for both reasons, and the centric occlusion of their teeth is no longer in harmony with the normal muscle pull (Fig. 2). We

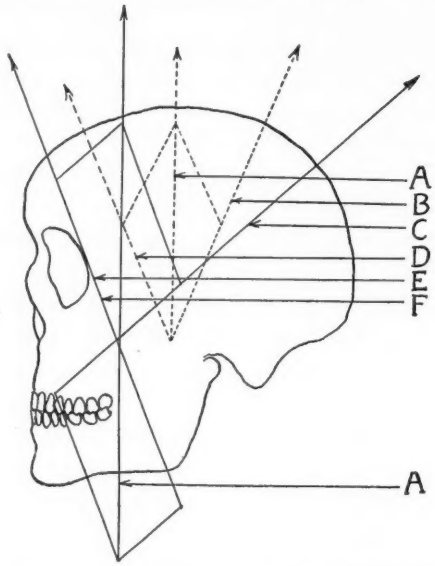


Fig. 1.—Wilson's parallelogram of forces, showing the directional pull of the muscles of mastication and their resultant force. *A*, Resultant force; *B*, deep fibers masseter; *C*, posterior fibers temporal; anterior fibers temporal; *E*, superficial fibers masseter; *F*, internal pterygoid.

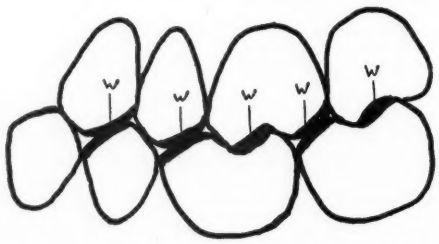


Fig. 2.—*W* indicates the inclines that have a tendency to wear because of mandibular movements. This wear produces a functional eccentric occlusal position not in harmony with muscle pull. Because patients chew primarily on either the right or the left side, the functional eccentric relation may not be a simple protrusion, but it may have a lateral component.

say that their centric relation and centric occlusion are not in harmony. Centric relation is the starting point of all occlusal movement. It is the most retruded position of the mandible from which lateral movements can be made at a given opening. This would imply that there is more than one centric relation, and that is true; however, there is only one centric relation at a given level. If the teeth occlude at that level, they must be in harmony with centric relation, or there will be damage to the supporting structures. This is true with both the natural and replacement dentures.

It is primarily because of this disharmony that 65 per cent of the teeth lost after the age of 35 years are lost because of periodontal conditions.[4]

Because of occlusal prematurities, which result when the patient attempts to close into his true centric relation, a damaging horizontal thrust on the teeth or temporomandibular joint results, and sooner or later pathology is present in the joint, periodontal structures, or both. One of Nature's defenses against damage from disharmony between centric occlusion and centric relation is the proprioceptive reflex. As soon as the patient strikes the prematurity, he reflexively moves to his functional eccentric position because it is more comfortable. Because of constant repetition, this reflex becomes conditioned with a resulting state of muscle memory. It then becomes extremely difficult to record centric relation. It is also possible that tissue changes take place behind the condyle because it seldom attempts to return to its centric position. This adds to the difficulty of recording centric relation. For these reasons it often cannot be done in one sitting.

## THE OPENING OR HINGE AXIS

There is not agreement on the existence of a hinge axis.[6, 7] It is important to those who believe in its existence, because by using it we can record centric relation at a level above the place where the proprioceptive reflex occurs, transfer our recording to an articulating instrument, and on the instrument, close down to the occlusal level. We can then study the damaging functional eccentric occlusal contacts out of the mouth, where our observations are not clouded by the proprioceptive reflexes. This is an important step in our diagnosis of problems in occlusal dynamics.

If the condition is one of long standing, it will be necessary to do something about the conditioned reflex. This might be taken care of by constructing a splint to mask the occlusal stimulus for a period of time.

To make the use of the opening axis, it should be located on the patient and transferred to the instrument. This is done with a face-bow. There are two kinds of face-bows in use today. These are the empirical, which most of us use, and the kinematic face-bow. The kinematic face-bow will locate the opening axis physiologically with extreme accuracy. With the empirical face-bow, we estimate the location of the axis by using anatomic landmarks.

An empirical face-bow transfer, carefully accomplished, is within a few millimeters of a kinematic transfer. The occlusion is about 100 millimeters distant from the opening axis; therefore, it is questionable if the additional accuracy (which would be extremely difficult to demonstrate clinically in the occlusion) warrants the additional effort.

The kinematic face-bow attaches to the mandible, and as the patient opens and closes, a pointer is adjusted until the axis of rotation is located.[8] It is then marked on the patient's face. Some operators make a small red tattoo mark at the center of rotation for future reference. The casts are then oriented on an articulating instrument with the face-bow. In most cases, this orientation is an equivalent position, and must be, because the vertical posts of most instru-

ments are not long enough for an exact orientation. We mount most of our casts with the plane of occlusion parallel, or nearly so, with the bows of the articulator, when, in reality, the plane of occlusion in the mouth is on an incline and not parallel with the Frankfort horizontal plane (Fig. 3). I can see no reason for an exact orientation (as recommended by Wadsworth[9] and McCollum[8]) except perhaps that we can judge the esthetic effect a little better.

There may be a limiting factor, theoretically. The condyle itself may be irregular, in which case there would be no exact axis of rotation. This is a theoretic consideration and would be difficult to demonstrate clinically (by occlusal inaccuracies).

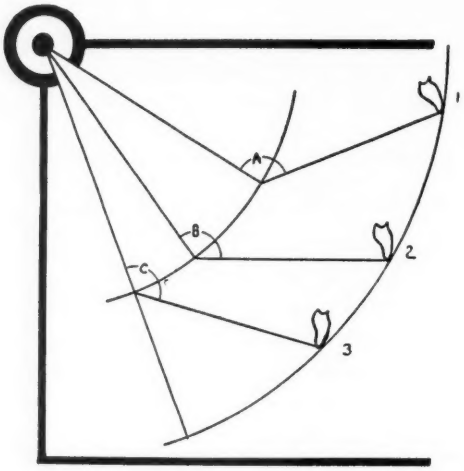


Fig. 3.—The various possibilities of mounting casts in relation to the hinge axis. The angles *A*, *B*, and *C*, formed by the condylar inclination and the occlusal plane, are equal; therefore, all three orientations should give equivalent results. *3* represents the position of a cast mounted from records made in relation to the Frankfort horizontal plane as recommended by Wadsworth and McCollum. This mounting may be valuable when considering the esthetic effect of tooth positions because the long axes of the teeth will be the same when the articulator is resting on the table as in the patient's mouth. This type of mounting is not possible with many of our present articulators because the vertical posts are not high enough. *2* represents the average mounting with the occlusal plane parallel to the bows of the articulator. A mounting as illustrated by *1* may be necessary on some of our present articulators to make space for particularly large casts.

Gross inaccuracies in the orientation of the casts on the articulator will manifest themselves in the occlusion. For instance, if the casts are mounted too far from the opening axis of the instrument (when the casts are closed to occlusion) there will be a premature contact in the posterior region. If they are oriented too close to the opening axis, the premature contact will be in the anterior region (Fig. 4). Rotational and lateral incline inaccuracies in orientation will also have marked effects on the occlusal pattern.

When the suprahyoid muscles have moved the mandible as far as they can, the external pterygoids take over and pull the condyles forward. When this happens, the opening axis changes to about the region of the mandibular foramina. This axis is of no practical use.

The rest position of the mandible is the position where the suprahyoid and infrahyoid muscles, the masticatory muscles, and the neck and back muscles are in a state of balanced tonus. The teeth are not in occlusion in this position. There is a free-way space in the natural dentition from 2 mm. to perhaps as much as 10 mm. It was thought that the condylar opening axis existed from this rest position to the occlusal position, and that the axis at the mandibular foramina started from rest position and was present to the wide-open position. If this were true, we would have a very excellent method of measuring the vertical dimension. The position at which the two arcs intersected would be rest position, and we could close to the occlusal position, having complete control over the free-way space.[10] This was found to be inaccurate. Some patients can keep their mandibles retruded while they open as much as an inch and a half in the incisal region,[8] thus having a usable opening arc of one and a half inches. To be on the safe side, we should not use this axis for more than a 2 or 3 millimeter closure in the incisal region. We can then close the vertical dimension on the instrument with a fair amount of accuracy in order to study and correct occlusal discrepancies for equilibration, rehabilitation, and denture work.

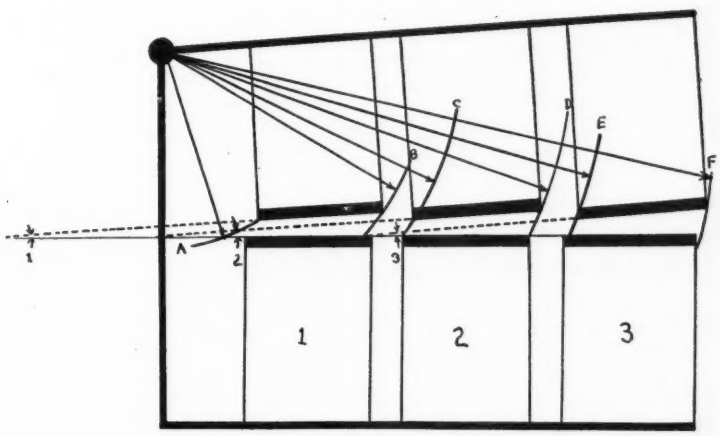


Fig. 4.—The effects of incorrect cast orientation. *1*, *2*, and *3* represent three identical occlusal tables, recorded at the same vertical opening. *2* has been oriented to the patient's hinge axis. *1* is too close to the hinge axis of the instrument, and *3* is too far away. Angles 1, 2, and 3 are equal because they were recorded identically; however, they will be equal only at that level. If the instrument is closed, Angle 1 will become smaller than Angle 2, and Angle 3 will be greater. Every point on each occlusal table will scribe an arc of a circle with its center at the opening axis as illustrated by arcs *A*, *B*, *C*, *D*, *E*, and *F*. On table *2*, arcs *C* and *D* coincide with the extremes of the table because the casts were oriented with the patient's hinge axis. On table *1*, arc *A*, drawn from the distal extreme of the maxillary table, misses the mandibular table completely, and arc *B*, drawn from the mesial extreme of the maxillary table strikes distal to the anterior extreme of the mandibular table. When the instrument is closed, there will be a premature contact in the anterior region. On table *3*, arc *E*, drawn from the distal extreme of the maxillary occlusal table, strikes mesial to the distal extreme of the mandibular table. Arc *F*, drawn from the mesial extreme of the maxillary table, misses the mesial extreme of the mandibular table. Here, there will be a premature contact in the posterior region when the instrument is closed.

ECCENTRIC POSITIONS OF THE TEMPOROMANDIBULAR JOINT

Many of these eccentric positions are spoken of as "nonfunctional" and are referred to as "static" occlusal positions. The teeth are functioning as a masticating apparatus for only about an hour a day. The remainder of the time the patient is going through these so-called "nonfunctional" movements. The nonspecific emotional stresses of modern living are translated into mandibular occlusal movements that we call bruxomania and bruxism. This translation results in a psychogenic breakdown of the supporting structures of natural and replacement dentures. If we give these *nonfunctional* movements the proper consideration, we can retard this process by more adequate stress distribution.

When the external pterygoids contract together with the closing muscles of the mandible a protrusion occurs. During this movement the condyles move forward and downward. This condylar drop can be compensated for in the occlusion by the orientation of the occlusal plane, the compensating curve, and the cusp height to establish a balanced occlusion.[1] Inaccuracies creep into our records of this movement for a number of reasons: First, we are recording the location of two points on a curved surface. The incline that we record on our articulating instrument will be based on two points of reference, one at the centric position, and the one we choose for the protrusive position which is usually about 6 mm. from centric position. The articulating surfaces of the joint are curved. This record is transferred to a straight incline on the instrument.

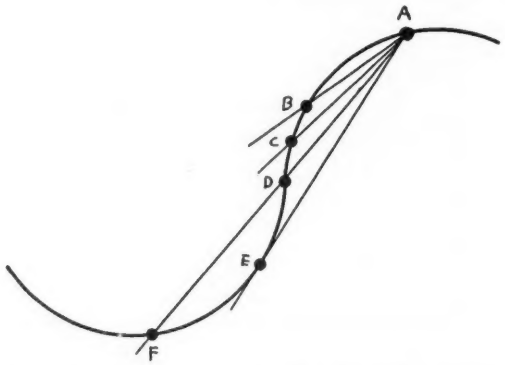


Fig. 5.—*A* indicates the centric position of the condyle of the mandible. *B, C, D, E,* and *F* indicate the various protrusive positions at which a record may be made. The lines drawn from position *A* to the various other positions show some of the possible variations in the protrusive records.

The 6 mm. distance which we must use in order to transfer the degree of inclination to our instrument (because our present methods are not accurate enough to use a shorter distance) is usually greater than the distance the patient moves the jaw in occlusal balance. The degree of inclination we have recorded from the curve is likely to be different at 6 mm. from what it would be if it were recorded at the functional distance (Fig. 5). The degree of inclination will be affected also by the amount of pressure the patient exerts on the recording baseplates, because of tissue displacement.

The lateral movements of the mandible are brought about when the external pterygoid muscle of one side contracts together with the closing muscles. Here, in an effort to simplify the problem, let us disregard the Bennett movement for a moment, and say that the condyle drops on the eminentia articularis on one side, and the condyle on the other side presents a simple rotation around a vertical axis. If we take a 6 mm. lateral record, we record the same possible inaccuracies we did with the protrusive record, and we will find that we cannot transfer our record to many of our "adjustable" articulators, because the "condyles" of the articulator are either further apart or closer together than the patient's condyles; therefore, the center of rotation is different. There are some articulators that will adjust to this record, such as the Hanau Kinescope, the House, the Stansbery Tripod, etc. In most cases, this record cannot be transferred to the popular Hanau model H. If we are dealing with high cuspal inclines, this becomes important, for the occlusal pattern will not be in harmony with this nonfunctional position and will cause rotation or undue skidding of denture bases (Fig. 6). The inaccuracy is similar to an attempt to put a nut on a bolt when the threads do not match. This vertical axis rotation is of less importance when monoplane teeth are employed.

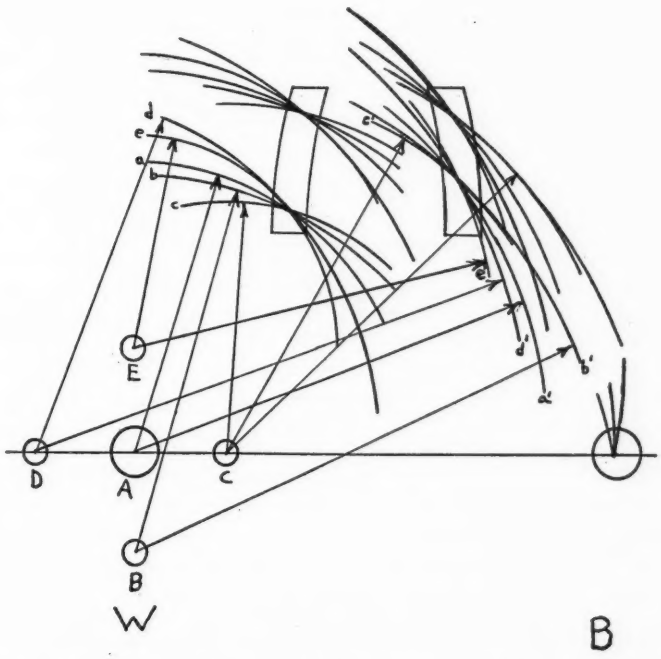


**Fig. 6.—The possible arcs scribed by occlusal schemes if different vertical axes of rotation are used. *W* is the working side. *B* is the balancing side. *A* is the center of rotation presented by the articulator. *B, C, D,* and *E,* are centers that may be presented by the patient. Many of our present articulators are not adjustable for these centers of rotation. When an occlusal scheme with high cusps is constructed on an instrument where this center of rotation is distant from the one presented by the patient, the contacts in lateral excursions will be traumatic, because they will cause the denture bases to rotate. The amount of trauma will be in direct proportion to the distance from the correct axis.**

## THE BENNETT MOVEMENT

The Bennett movement is the lateral shift of the entire mandible which takes place when the patient's mandible makes a lateral excursion. This is probably brought about by the internal and external pterygoid muscles working together on the side where the condyle moves forward (the balancing side). The external pterygoid pulls forward and medially, while the internal pterygoid has a medial as well as an upward line of contraction.

The Bennett movement is not necessarily a simple lateral shift. The condyle on the working side of the occlusion may move laterally and mesially, laterally and distally, laterally and superiorly, laterally and inferiorly, or various combinations of these directions. This may have either a positive or a negative effect on the inaccuracy of equivalent articulator movements, depending on the directional component of the Bennett movement.

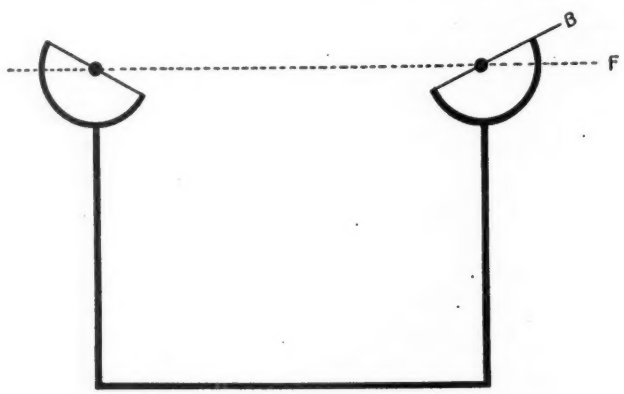


Fig. 7.—The vertical component of the Bennett movement. *F* indicates a fixed axis of an articulating instrument that will not adjust for the vertical component of the Bennett movement, when it is present. *B* indicates a broken axis that will adjust for this position.

Many of our present instruments will not record the Bennett movement. Some follow formulas which seem to have no scientific basis. Fixed axis instruments, which are the most popular today, will not adjust to the vertical components of the Bennett movement when it is present (Fig. 7). Because of tissue resiliency, complete dentures will often to some extent forgive some of the sins of inaccuracy.[11, 12] Natural teeth with their more rigid anchorage are not always so forgiving. Mouth reconstruction and dentures with high cuspal inclines, built to inaccurate records, may well be dental poisons rather than dental remedies.

The Bennett movement has a marked effect on the occlusal pattern of teeth with high cuspal inclines because it regulates the path through which the cuspal interdigitations must pass. If the occlusal pattern is not in harmony with the Bennett movement, occlusal trauma will result during the *nonfunctional* mandibular movements. The Bennett movement has considerably less effect on monoplane teeth.

## CHEWING CYCLES

At the present time there is not complete agreement on chewing cycles.[13-16] They seem to be affected by the occlusal pattern, the resistance offered by food, and the apparatus used to record them. It is thought by some that there is a flatter chewing cycle with monoplane teeth arranged on a flat plane or on a compensating curve, while the cycle is more nearly vertical with high cuspal inclines, or with monoplane teeth set on a reverse curve. If this is true, it may be due to the proprioceptive and exteroceptive reflex control of the mandibular movements. Less resistance to the movement is offered by monoplane teeth. Therefore, they would have to make a greater excursion to cause the same amount of stimulation to the reflex. It is quite probable that the skidding of the bases of well-fitting dentures on good supporting ridges is the same no matter what the degree of cuspal incline because of this reflex control.

## SUMMARY AND CONCLUSION

It is extremely important to consider both the dynamic and static aspects of occlusion.

The recording of the opening axis and the transferring of it to an articulator are of considerable value in the diagnosis and treatment of occlusal malfunction.

Improper orientation of the casts on an articulator can result in the construction of an occlusal pattern that is not in harmony with the temporomandibular movements. This might result in overstimulation and rapid breakdown of supporting structures of either natural or replacement dentures.

If high cuspal inclines are used, improper orientation of the vertical axis of rotation might cause damaging cuspal interference during lateral excursions. Many of our articulating instruments are not adjustable to this center of rotation.

The Bennett movement has an effect on the cuspal interdigitation during lateral excursions. An accurate equivalent of this movement cannot be duplicated on many "adjustable" articulators.

The vertical component present in the Bennett movement of some patients cannot be duplicated on a fixed axis articulator, but its equivalent can be reproduced on a broken axis instrument, or on an adjustable articulating jig, such as the Stansbery Tripod.

While mandibular movements cannot be reproduced with complete accuracy on an articulator, we should reproduce them with as much accuracy as possible to minimize damage to supporting structures from occlusal disharmony.

Monoplane teeth forgive many of the sins of inaccuracy over which we have no control.

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# MOLDING AND STAINING ACRYLIC RESIN ANTERIOR TEETH

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THE ADVENT OF ACRYLIC resins into the field of artificial tooth fabrication has opened new vistas in the field of esthetics. The ability to reproduce the shadings and blending of colors in natural teeth, to reproduce anomalies of color and natural characteristics, is much more nearly attainable by the use of this material than it was with porcelain.

The method by which this material can be turned to the advantage of esthetic improvement in the fabrication of denture teeth is not a difficult one, but an orderly, organized sequence of procedure must be observed.

This procedure was developed originally by Hardy,* some years ago. It has given us the means for developing strikingly effective esthetic results.

## EQUIPMENT

An orderly plan of arrangement for the variously colored powders, liquid, and other items necessary is important (Fig. 1). The container is an ordinary file box. The bottles are 1 ounce toy nursing bottles which may be obtained in any department store. Each bottle is labeled to show the color of stain it contains (Fig. 2). The syringe, needed for the application of the monomer, is made up of an 18 or 19 gauge needle fastened to an empty Novocain carpule by means of a small section of rubber tubing at one end, while a rubber squeezer taken from a silicate or cement liquid dropper is attached to the other end of the carpule to complete the syringe. A scalpel or razor blade is needed for developing check lines and the outlines of washed-out silicates. The other equipment necessary is a mixing jar, a press, a bottle of monomer, two dappen dishes in which to place the stains during the molding process, an instrument suitable for picking up small amounts of the stains when needed (a Vehe carver), and a flask press.

## MOLDING THE TEETH

A tooth body shade of acrylic resin is selected, and a sufficient amount of this polymer to fabricate six anterior teeth, or twelve if two sets are to be fabricated simultaneously, is placed in the mixing jar. This is wetted down with monomer by means of the syringe until it is thoroughly moistened (Fig. 3). The cover is then placed on the jar, and the mix is allowed to stand until it has passed the doughy stage, and has a rubbery consistency. The stiffer the mix is allowed

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*Hardy, Irving R., Professor of Prosthodontia, Tufts College Dental School.

to become, within the limits of workability, the more sharply the detail on the metal mold will be transferred to the acrylic resin teeth.

When the mix has set to the desired consistency, it is portioned out among the tooth receptacles, in the lingual half of the metal mold, in sufficient amounts to assure a complete pattern of each tooth when the mold is closed, plus a small amount of excess in relation to each tooth as well (Fig. 4).

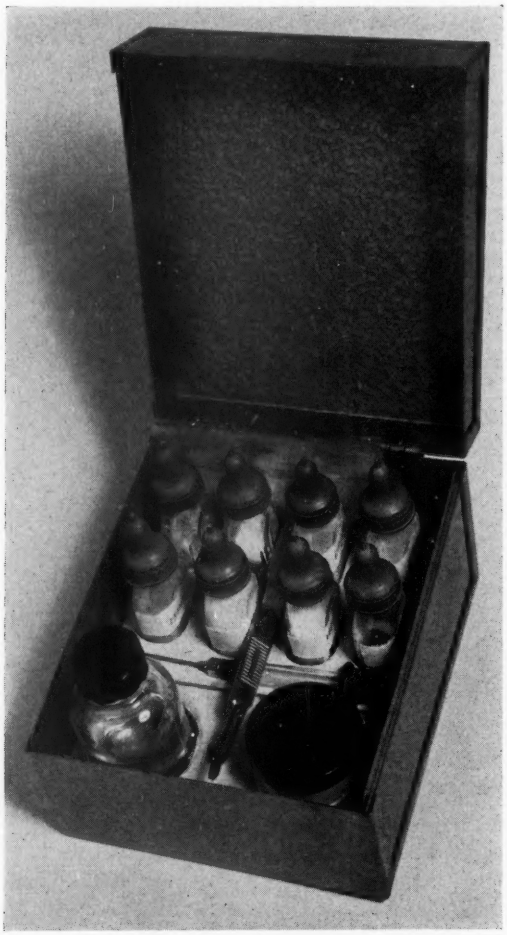

Fig. 1.—The staining kit is made up of: a metal file box, toy nursing bottles, a mixing jar, a bottle of monomer, a scalpel, and a monomer syringe. The staining kit was designed By Peter Cordiero, D.D.S., Bombay, India, and Williard Coy, D.M.D., Tufts College Dental School.

Then the acrylic resin in the mold is covered with a sheet of wet Cellophane, the labial half of the mold is positioned, and firmly closed in the press. If it is desired to mold two sets of teeth simultaneously, a second set of teeth can be prepared for pressing in the same manner, while the first set remains in the press (Fig. 5).

Fig. 2.—The materials needed to stain teeth and the monomer syringe.

Fig. 3. Fig. 4.

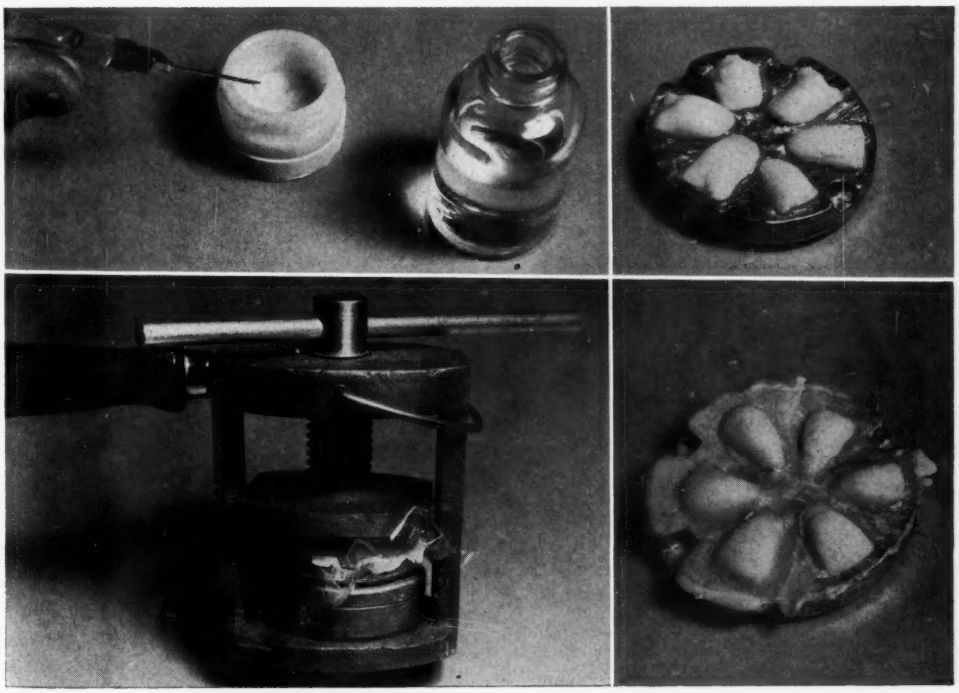

Fig. 5. Fig. 6.

Fig. 3.—The monomer is added to the body shade resin.
Fig. 4.—Acrylic resin at the rubbery stage is placed in the lingual half of the mold.
Fig. 5.—Cellophane is placed over the resin, and the mold is assembled and compressed tightly in a flask press. Note the excess resin being squeezed out from between the halves of the mold.
Fig. 6.—The labial contours of the resin teeth after being pressed.

If the resin is kept under pressure in the mold, it will retain the proper consistency until it is removed for modification. When the mold is removed from the press, it is opened and the Cellophane is removed, displaying the labial surfaces of the soft acrylic resin teeth (Fig. 6).

## INCISAL COLOR PATTERNS

Sections of the rubbery resin are cut away from the incisal region of each tooth to provide space in the mold for the incisal resin (Fig. 7). The pattern of this resection is different for each tooth, but it must be done in a pattern that is in harmony with the incisal translucency of each of the anterior teeth as found in nature. For example, to achieve a natural incisal effect a wedge, with its base at the incisal edge, is cut out of one central incisor, and a slice is removed from the distal corner of the other central incisor. This avoids regularity and duplication. In all of these incisal resections, the cut section of resin must be cut completely through the depth of the tooth so that it is completely removed to expose the lingual portion of the mold. If this is not done, the effect of the incisal color added in this region will be nullified by the residual body color which will show through the incisal material.

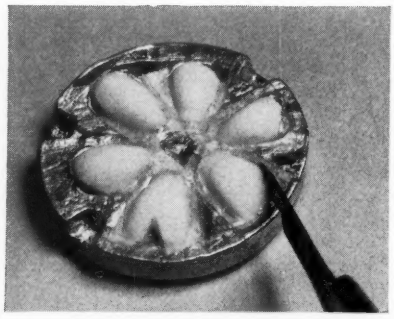

Fig. 7.—The flash is removed and the patterns for incisal translucency are cut out.

Since natural lateral incisors generally exhibit a broader area of translucency than either the central incisors or cuspids, a greater amount of resin must be removed from their incisal regions than from the corresponding portion of the other anterior teeth. At the same time, an underlying theme of irregularity must be maintained.

The lateral incisors are prepared for the addition of incisal color by making an oblique cut through the resin of the mesial and distal surfaces of the tooth. The cuts are started at points one-fourth of the distance from the incisal edge to the cervical end of the tooth, and are directed obliquely toward the incisal edge. These two incisions meet to form an apex pointed incisally at a point 2 or 3 mm. above the incisal edge of the tooth, and thus the entire incisal edge of the tooth is removed. The pattern of irregularity so essential to the simulation of natural teeth is maintained by varying the *angles* of the two oblique incisions, so that on one lateral incisor, the mesial cut is shorter than the distal cut, and, on the other tooth, the distal cut is shorter than the mesial cut (Fig. 7).

Since the cuspids have a greater labiopalatal dimension than the incisors, and since they terminate in comparatively thick cusps rather than in thin incisal edges, their translucency is limited generally to regions of the mesial and distal contact areas.

To simulate these translucent areas in cuspids, the portions of the teeth formed by the junction of the mesial and distal surfaces with their respective inclined planes of the cusp are sliced off. However, a pattern of planned irregularity must be followed. Therefore, while we adhere to the essential requirements of the natural translucent pattern of the cuspids, we refine this further to meet the need for irregularity by using a modification of the method applied to the lateral incisors. The cut made to remove the distal contact area will be longer and inclusive of more tooth substance than the cut made to remove the mesial contact area. The reverse will be done on the other cuspid (Fig. 7).

### RECONSTRUCTION OF THE INCISAL REGIONS

One of the toy nursing bottles is filled with "light incisal" powder. The rubber nipple terminates in a cylindrical spout with a diameter approximately that of a common pin. This makes it possible to dispense the acrylic resin powder in such a way that it can be controlled and placed in restricted areas in the mold. The teeth are wetted with monomer by means of the syringe. Then the light incisal powder is added in liberal quantities to the resected portions of the teeth (Fig. 8). Then, additional monomer is applied until all of the light incisal powder is thoroughly moistened (Fig. 9). Some of the incisal powder may be washed away as the monomer is added. If this occurs, more powder must be added at once, and this may require further wetting with monomer. These procedures are repeated until enough incisal resin has been added to make sure that the mold will not be underpacked.

### ADDITION OF THE CERVICAL COLOR

A nursing bottle filled with shade 70 acrylic resin powder is used. It is applied to the teeth according to the location and degree that cervical coloring is distributed in natural anterior teeth.

The six teeth are wetted with monomer, then shade 70 powder is dusted over the cervical portion of the labial surface of the central incisors. It is placed to cover about one-third of the face of the tooth in an incisal direction from the cervical margin. It is placed over about one-sixth of the labial surface of the lateral incisors in an incisal direction from the cervical margin. It is placed over the cuspids to cover approximately one-half of the distance from the cervical margin to the cusp point (Fig. 10).

After the powder has been dusted over all six teeth, these new additions of polymer are moistened thoroughly with monomer. The cervical portions of the teeth are inspected, and if any do not appear to show sufficient emphasis of color, more shade 70 powder is added where desired, and the teeth are re-moistened.

The addition of incisal and cervical shades is now consolidated. A sheet of Cellophane is dipped into a pan of water which is kept boiling close at hand. It is then laid over the labial surfaces of the teeth after the last bit of cervical shade has been added and wetted. Then the mold is closed and placed under pressure in a small crown and bridge press (see Fig. 5), and in this position it is immersed in the boiling water for *one minute*. The mold must not be allowed to remain in the water more than one minute, or the teeth will become too hard to allow for the proper execution of their further modifications. After they have been boiled for one minute, the teeth will be of a leathery consistency, exactly suited to the accomplishment of the next procedure (Fig. 11).

Fig. 8. Fig. 9.

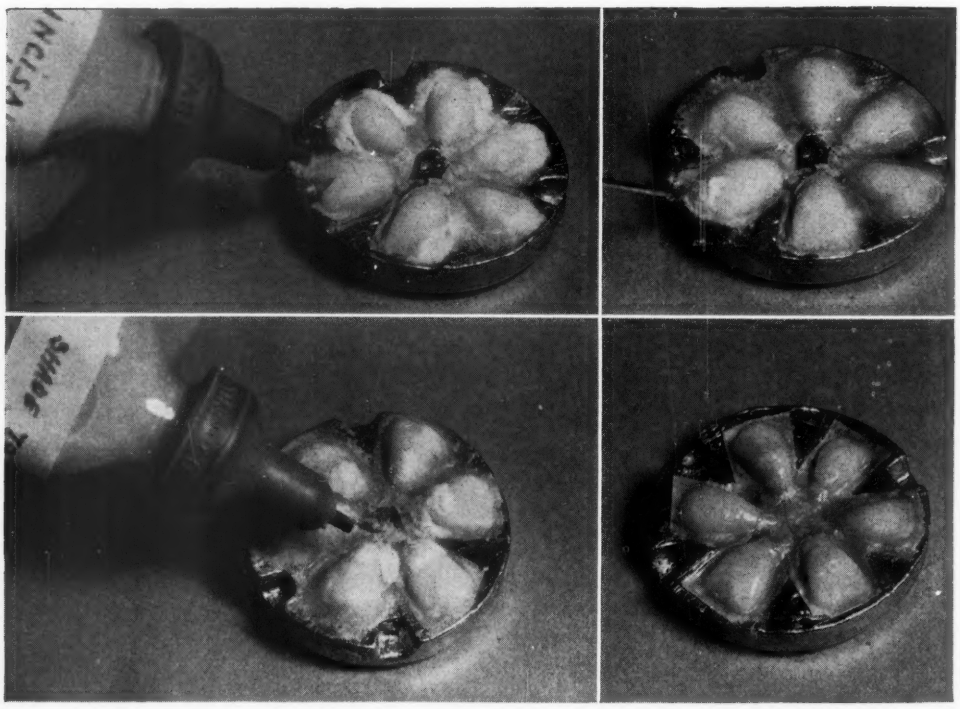

Fig. 10. Fig. 11.

Fig. 8.—The light incisal powder is substituted in all places where the rubbery resin has been removed.

Fig. 9.—The incisal powder is wetted with monomer. Note that this has been done on all except one tooth.

Fig. 10.—Cervical yellow powder is being added to all of the teeth. This powder will be wetted in the same manner as shown in Fig. 9.

Fig. 11.—The teeth after boiling one minute. The resin has a leathery consistency.

## ADDITION OF STAINS

When the press is removed from the water, it is released, the mold is opened, and the Cellophane is removed. The final phase in the fabrication of hand-molded, stained acrylic teeth is the addition of check lines, simulated silicate restorations, and opaque areas in the teeth.

## CHECK LINES

Check lines, like incisal translucency, must be placed in a pattern of irregularity. For example, if a check line is placed in the labial aspect of the right central incisor, a second check line might be introduced in the labial surface of the left cuspid. At the same time, if this check line is located either to the mesial or the distal of the midline of the tooth, it still further augments the appearance of naturalness. A check line usually starts from the incisal edge of the tooth, and it may extend cervically to almost any point on the tooth. As a general rule, I have found that a line which extends approximately three-fourths of the way from the incisal edge to the cervical margin of the tooth is desirably effective.

A scapel or razor blade, a dapin dish with a small amount of brown stain powder, and an instrument with which to carry it to the tooth are the equipment needed. With the acrylic resin at the leathery consistency which is best suited to the addition of check lines, the mold is opened and the Cellophane is removed.

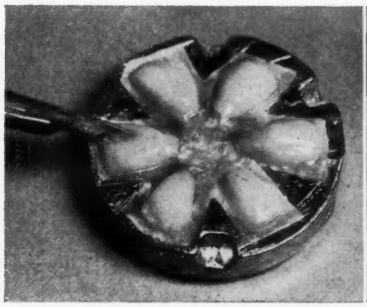

Fig. 12.

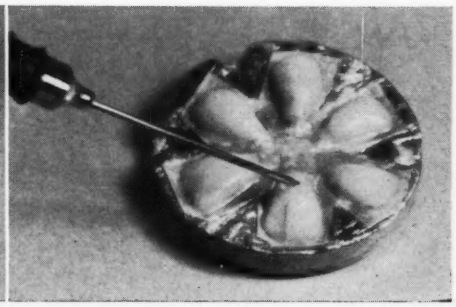

Fig. 13.

Fig. 12.—The incision in the surface of a central incisor for the reception of stain to simulate a check line. The stain is added in slight excess while the scapel holds the cut open.
Fig. 13.—The stain is wetted with monomer.

The point of the scapel is placed where we wish the highest point of the check line to be, and care is taken to make sure that the proposed line of incision is parallel with the long axis of the tooth. Then with a single definite stroke of the scapel in an incisal direction, an incision, 1 to 2 mm. deep, is made which will extend the entire length of the check line (Fig. 12). When this has been done, the scalpel is held within the confines of the incision and rotated slightly on its long axis to spread the cut open. With the base of the incision thus exposed, the brown stain powder can now be introduced into the cut with greater control and accuracy. A small amount of the stain powder is picked up on the spoonlike end of a Vehe carver, or some similar instrument, and dropped into the incision along its entire length, using the side of the scalpel blade as a guide. To avoid developing a check line that is darker than may be desired, only a slight amount of stain is used along the length of the cut. It must be kept in mind that the tooth is partially processed, and that the amount of stain placed into the cut is not sufficient to completely bridge the mesiodistal gap created by the incision itself. In other words, this cut will not wholly reseal

itself when the mold is closed. Additional acrylic powder, stain or otherwise, must be added to fill the space created by the incision and its subsequent spreading. If this is not done, there will be a groovelike indentation along the surface of the tooth where the check line was made. Since we do not wish to create too dark a check line, we use only a small amount of stain powder. When we have added the desired amount of brown stain, the scalpel is removed, and the remainder of the space created within the incision is filled with transparent acrylic resin powder. If the brown stain used is not overly dark, the incision may be filled to a slight excess with stain alone (Fig. 13). The entire length of the check line is then wetted with monomer.

### SIMULATED SILICATE RESTORATION

Silicate restorations are simulated in the same manner as the check lines, differing only in the location and form of the initial incision into the leathery acrylic resin. Since the stained margin of an old silicate filling is to be outlined, the cut will naturally take a semilunar or modified semilunar form, in imitation of the outline of a cavity preparation for this type of filling. It is located on the mesial or distal side of the tooth, and it can be made to encroach, to varying extents, over the labial surface of the tooth since the convexity of the cut is developed toward the midline of the tooth. The stain is placed in the same way as for a check line, except that the cut cannot be pried open in the same manner as for a check line. Instead, the flap of resin formed by the semilunar cut is retracted, a section at a time, while the brown stain powder is sifted into the cut. In order to reproduce the somewhat washed-out appearance in the color of the silicate restoration, a small amount of opaque white stain is pushed under the flap just prior to the addition of the brown stain (Fig. 14).

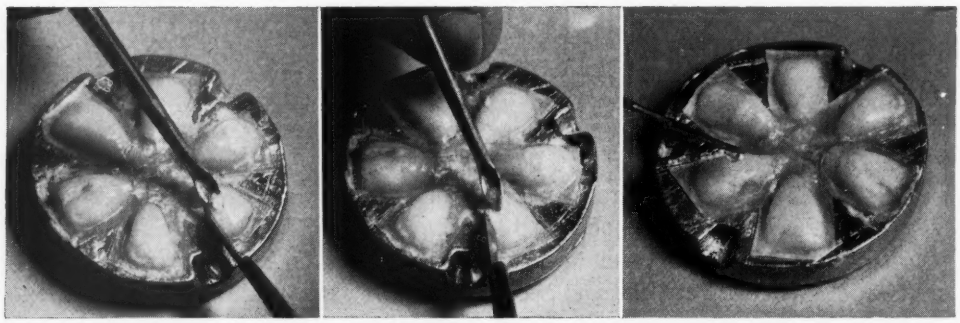

Fig. 14. Fig. 15. Fig. 16.

Fig. 14.—A cut has been made with the contour of a silicate restoration. The scapel spreads the cut while the opaque white stain is placed under the flap of resin.

Fig. 15.—The scalpel continues to hold the incision open while the brown stain is dusted along the line of the cut. Note the check line in the second tooth to the left of the scalpel.

Fig. 16.—The stain for the simulated silicate restoration is wetted with monomer.

If necessary, transparent acrylic resin powder is dusted over the line of incision to make sure that it is completely filled (Fig. 15). When this has been accomplished, the area is wetted with monomer, just as the check line had been at this corresponding stage in its formation (Fig. 16).

## OPAQUE AREAS

Areas of opacity are added to the labial surfaces of the leathery acrylic resin teeth in order to accomplish the intended goal; namely, a truly natural-appearing set of anterior teeth.

Consistent with the theme of variation and irregularity which has been followed closely, we must continue to avoid repetition and duplication in placing the opaque areas. If we place an opaque area on the right central incisor, it is best to avoid placing one on the left central incisor, and place another opaque spot on the left lateral incisor or the left cuspid. While it is true that opacities may occur in any or several teeth, I believe that restraint in distributing them contributes to a much more desirable result.

Their location on individual teeth is a matter which must also be considered. In general, they are most effective when located in the incisal third of the tooth, in areas free of incisal translucency. But, on occasion they are in harmony with

Fig. 17. Fig. 18.

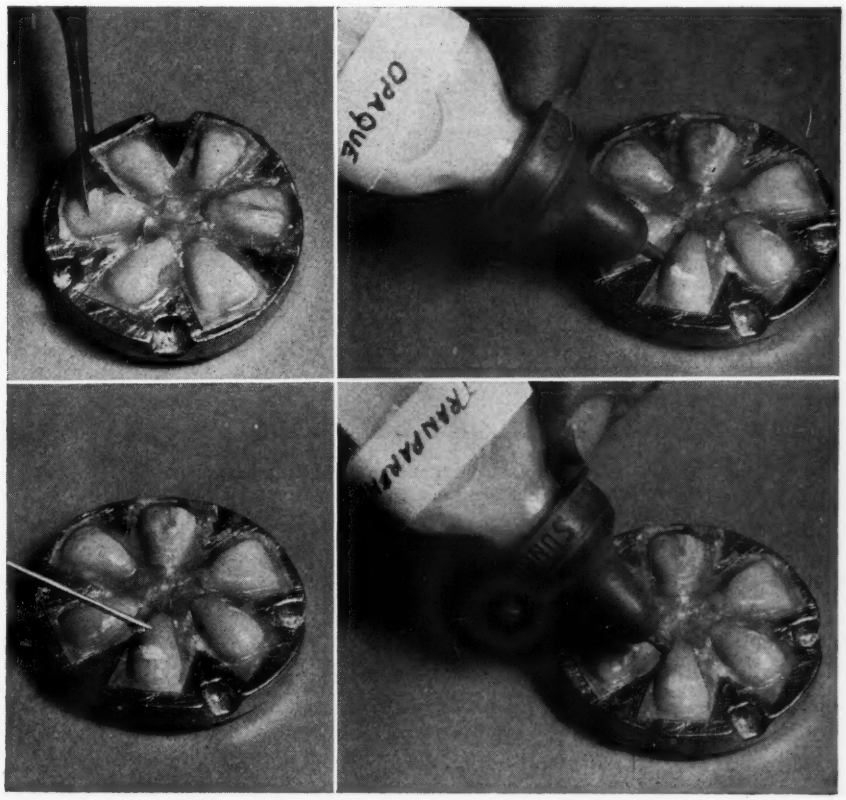


Fig. 19. Fig. 20.

Fig. 17.—A wedge of resin is removed from the labial surface of an upper cuspid preparatory to the forming of an opaque spot.

Fig. 18.—Opaque white powder is added where the wedge has been removed.

Fig. 19.—The opaque white powder is wetted with monomer.

Fig. 20.—Transparent acrylic resin powder is added over the opaque area directly after the first application of monomer. Then this is wetted with monomer once more.

a natural effect when they are placed in the cervical third of the tooth. When it is used with discretion, the opaque spot is in proper relationship to its surroundings at almost any point on the labial surface of the tooth.

To produce the appearance of an opaque spot on the surface of an acrylic resin tooth, a wedge 1 or 2 mm. deep is cut out of the surface of the tooth with a scalpel or razor blade, or one or two small, irregularly shaped sections of it are gouged out (Fig. 17). A small amount of "opaque white" polymer is placed in a dappen dish, and some of this is carried on the spoon end of a Vehe carver into the opening created by the removal of the wedge, or into the gouged-out sections of the tooth. The opening is filled or nearly filled with opaque white powder (Fig. 18). The powder can be sifted directly from the bottle into the holes, if care is taken. It is then wetted down with monomer (Fig. 19), and immediately the area is dusted over freely with transparent acrylic resin powder directly from the dispensing bottles and wetted again (Fig. 20).

Transparent acrylic resin powder is dusted liberally over the labial surfaces of all six teeth, and this is wetted with monomer. While the surfaces of the teeth are still moist, a sheet of wet Cellophane is placed over them, the mold is closed and placed under pressure in a small press. This will produce teeth of greater density, and a more highly polished surface.

Fig. 21.—The processed teeth showing check lines, simulated silicate restorations, and opaque areas.

It is very important to allow the mold to bench cure under pressure for approximately one-half hour. Just before the final closure of the mold, the teeth were moistened with a final application of monomer. This monomer remains in excess when the mold is placed in the press prior to the final processing. If the freshly packed teeth in the mold are placed directly into the boiling water, the monomer volatilizes too rapidly, and this can result in porosity in the finished teeth. However, if the resin teeth are allowed to bench cure for one-half hour before they are boiled, the excess monomer is permitted to volatilize slowly and gradually. After this bench-curing period, the press containing the mold is placed in boiling water for one-half hour for processing the resin. Then the mold is chilled in the press under cold running water for one or two minutes. When it is thoroughly chilled, the press is released and the mold is removed. The mold is opened, the teeth are removed, and the flash resulting from the excess resin is buffed off (Fig. 21). The teeth are then finished and ready for use.

SUMMARY

A technique for molding and staining acrylic resin anterior teeth has been described. The procedure is carried out in an orderly and logical sequence. A tooth-body shade of acrylic resin in a rubbery consistency is pressed in a metal mold for six anterior teeth. Then the mold is opened and the teeth are modified to include incisal translucencies and cervical yellow. These are added according to a pattern of irregularity which closely simulates the appearance of natural teeth. The mold is closed and boiled for one minute so that the resin is partially cured to a leathery state. Then the mold is opened, and check lines, silicate restorations, and opaque spots are added to provide an appearance of naturalness. After bench curing it is boiled for thirty minutes to complete the curing process. The mold is chilled and the teeth are removed from the mold. After the flash is buffed off, the teeth are ready for use.

The molding of acrylic anterior teeth makes possible the attainment of esthetic results which are most gratifying. By a careful selection and distribution of stains, anterior teeth may be made which are in harmony with the physiognomy of the individual patient of any age.

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# EFFECT OF TIN-FOIL SUBSTITUTES ON THE STRENGTH OF DENTURE BASE RESINS

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THE USE OF TIN-FOIL SUBSTITUTE as a mold lining for acrylic resin processing has been the principal subject of at least two reports.[1, 2] Also, Peyton and associates[3] included data on the transverse strength of resins processed in the tin-foil substitute in his report on self-curing resins. Ferguson[1] reported such data for heat-curing resins. Ferguson's specimen preparation followed the standard method described in the American Dental Association specification No. 12 for denture base resins, and it is assumed that Peyton followed the same procedure. Ferguson made one exception. When rubber dam was used as a mold lining, the specimens were processed about one-half the standard thickness in order to avoid the removal of a relatively thick layer of the resin after processing. However, no specimens processed with other tin-foil substitutes as a mold lining were made to these dimensions.

Neither Ferguson nor Peyton found any significant difference between the transverse strength of resins processed in tin foil and that of resins processed in tin-foil substitute.

Sweeney[4, 6] suggested that the different dimensional behavior of resins processed in tin foil and in tin-foil substitute was caused by adsorption of water through the substitute film (V-COTE) during processing. Sweeney,[5] also, showed that resin protected from contact with water by tin foil during processing did not craze; however, when water was allowed to come in contact with the resin at an elevated temperature, the resin was susceptible to crazing due to internal stresses set up by water sorption.

On the basis of Sweeney's explanation of warpage and crazing of denture base resin and other observations,[2] an investigation was made to determine the effect of tin-foil substitute on the transverse strength of the resin.

## EXPERIMENTAL PROCEDURE

Since it was desired to approximate clinical use of the material and to study the surface effects of the mold lining, the specimen molds were made only 0.1 mm. thicker and wider than the size required for the transverse test specimen (65 by

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10 by 2.5 mm.). The excess 0.1 mm. of resin was removed by sanding on 400 A Carborundum paper. This specimen preparation was thought to simulate the surface effects of the mold lining in denture construction better than the preparation of specimens by machining from 62 by 65 by 5 mm. resin blocks, as called for in the standard specification No. 12. Transverse strength tests were performed on specimens immediately after deflasking, and after four days' storage in water at 37° C. Table I shows the denture resins and tin-foil substitutes used. Two of the resins were of type I, heat-curing resins, and three were of type II, self-curing resins. A resin of type I was processed with different tin-foil substitutes. Control specimens were prepared in molds lined with with tin foil.

TABLE I

| CODE NAME | TYPE | PURCHASE DATE |
|---|---|---|
| *Denture Resins:* | | |
| R1 | Self-curing (type II) | October, 1953 |
| R2 | Self-curing (type II) | October, 1953 |
| R3 | Heat-curing (type I) | January, 1954 |
| R4 | Heat-curing (type I) | January, 1954 |
| R5 | Self-curing (type II) | October, 1953 |
| *Substitutes:* | | |
| S1 | Alginate | October, 1953 |
| S2 | Alginate | October, 1953 |
| S3 | Sodium silicate | October, 1953 |
| S4 | Silicone | January, 1954 |
| S5 | Alginate | January, 1954 |

The warpage of heat-curing denture bases resulting from the use of tin-foil substitutes has been shown by Fairhurst and Ryge.[2] To study whether warpage occurs in self-curing resins as in heat-curing resins, specimens were made as previously described. Three different mold lining conditions for each resin were used: (1) tin foil on both sides; (2) tin foil on one side and tin-foil substitute on the other; (3) tin-foil substitute on both sides. These specimens were not sanded except to remove the flash. The length of each bar was measured with a micrometer dial gauge equipped with pointed anvils; measurements were taken at fine reference points scribed on each end of the specimen. Measurements were taken immediately after deflasking and again after seven days storage in water at 37° C. Photographs were also taken immediately and after seven days storage, with the specimen placed on a flat surface.

## RESULTS AND DISCUSSIONS

The data for the transverse strength tests* are shown in Table II. The values reported represent averages for at least four identical specimens. The data chosen for use in Tables II, III, and IV are representative of a total of over 200 specimens.

*Transverse tests were performed in air in accordance with the procedure specified in ADA Standard Specification #12 for Denture Base Resin (January, 1942, edition).

TABLE II. DEFLECTION AND TRANSVERSE STRENGTH VALUES, AVERAGE OF AT LEAST FOUR SPECIMENS, AT ½ HOUR AND 4 DAYS FOR HEAT-CURING AND SELF-CURING DENTURE BASE RESINS

| TYPE OF RESIN | MOLD LINING | CURING CONDITIONS | AGE AT TEST | DEFLECTION AT: | | LOAD AT FAILURE (GM.) |
|---|---|---|---|---|---|---|
| | | | | 3,500 GM. | 5,000 GM. | |
| I Heat-curing | Tin foil | 9 hours at 160° F. | ½ hour | 1.31 | 2.69 | 7,900 |
| | | | 4 days | 1.52 | 2.98 | 6,800 |
| | Tin-foil Substitute (rec. by mfg.) | 9 hours at 160° F. | ½ hour | 1.52 | 3.06 | 6,800 |
| | | | 4 days | 1.53 | 3.28 | 6,800 |
| II Self-curing | Tin foil | 2½ hours | ½ hour | 2.58 | 6.14 | 5,400 |
| | | | 4 days | 1.64 | 3.25 | 6,500 |
| | Tin-foil Substitute (rec. by mfg.) | 2½ hours | ½ hour | 2.84 | 7.01 | 5,400 |
| | | | 4 days | 1.85 | 4.28 | 6,300 |

TABLE III. DEFLECTION AND TRANSVERSE STRENGTH VALUES, AVERAGE OF AT LEAST FOUR SPECIMENS, FOR SELF-CURING DENTURE BASE RESINS AS AFFECTED BY CURING TIME AND AGE OF SPECIMENS

| | CURING TIME | AGE AT TEST | DEFLECTION AT: | | LOAD AT FAILURE (GM.) |
|---|---|---|---|---|---|
| | | | 3,500 GM. | 5,000 GM. | |
| Type II Self-curing | 2½ hours | ½ hour | 2.5 mm. | 7.5 mm. | 5,100 |
| | 2½ hours | 4 days | 1.7 mm. | 4.5 mm. | 6,000 |
| Type II Self-curing | ½ hour | ½ hour | .....failed..... | | 3,200 |
| | 1 hour | ½ hour | 3.6 mm. | 9.0 mm. | 5,100 |
| | 2 hours | ½ hour | 2.0 mm. | 4.8 mm. | 5,500 |

TABLE IV. DEFLECTION AND TRANSVERSE STRENGTH VALUES, AVERAGE OF AT LEAST FOUR SPECIMENS, FOR A HEAT-CURING DENTURE BASE RESIN AS AFFECTED BY THE USE OF VARIOUS BRANDS OF TIN-FOIL SUBSTITUTE AND OF TIN FOIL AS A MOLD LINER. THE TRANSVERSE TESTS WERE PERFORMED IMMEDIATELY AFTER DEFLASKING

| CODE NAME OF TIN-FOIL SUBSTITUTE | DEFLECTION IN MM. AT | | LOAD AT FAILURE (GM.) |
|---|---|---|---|
| | 3,500 GM. | 5,000 GM. | |
| S5 | 1.51 | 3.06 | 6,800 |
| S2 | 1.50 | 3.04 | 7,400 |
| S1 | 1.73 | 3.16 | 7,000 |
| S4 | 1.51 | 3.00 | 7,000 |
| S3 | 1.74 | 3.45 | 6,900 |
| Tin foil | 1.31 | 2.69 | 7,900 |

An inspection of the data will show that there is a slight difference in the strength of resins processed with tin foil and with tin-foil substitute. In the heat-curing resins, the difference is most pronounced immediately after deflasking; in the self-curing resins the difference is not evident in the values for load at failure; however, the table indicates that the specimens processed in molds lined with tin-foil substitute have somewhat higher deflection values both at 3,500 Gm. load and at 5,000 Gm. load than those processed in molds lined with tin foil.

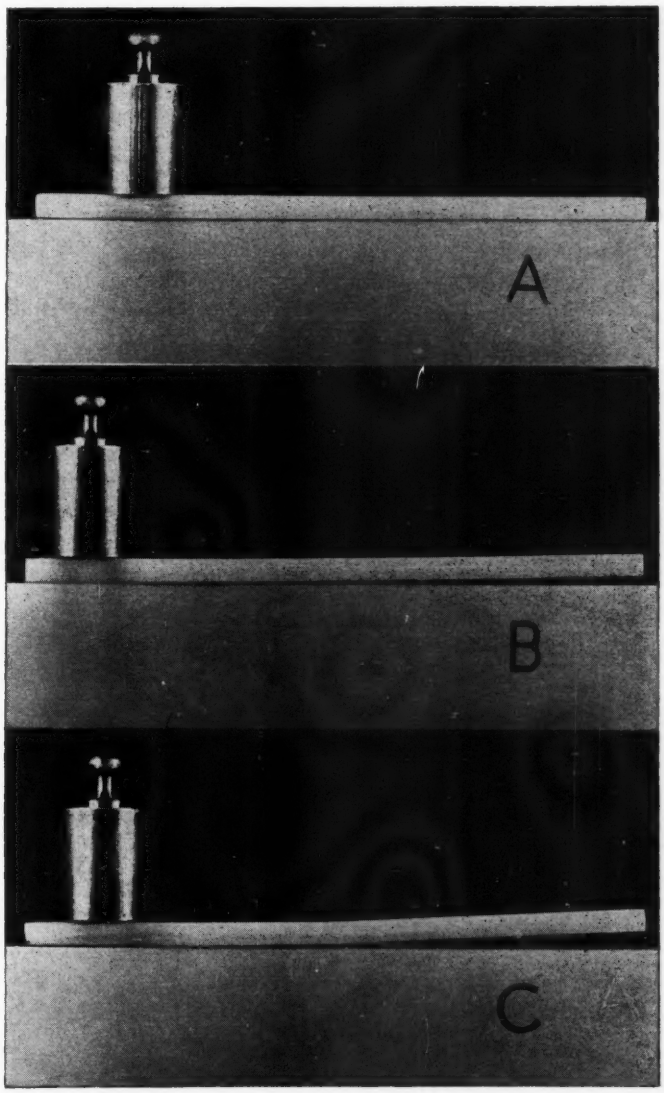


**Fig. 1.—Acrylic resin transverse test specimens processed in molds lined with: *A*, tin foil on both sides; no warpage is evident after storage in water at body temperature for one week; *B* and *C*, tin foil on one side (convex side), tin-foil substitute on the other side; warpage is evident immediately after deflasking (*B*) and increases by storage in water at body temperature for one week (*C*).**

Whether the difference in strength is significant in clinical use, is difficult to determine from these tests. For a complete evaluation of the effects of mold lining materials, however, this evidence is important in connection with the warpage and dimensional change behavior reported for resins processed in a mold lined with tin-foil substitute.[2]

Heat-curing and self-curing resin specimens which were processed in a mold lined with tin foil increased in length varying from 0.2 to 0.3 per cent. Heat-curing resin specimens processed in tin-foil substitute did not increase appreciably in length, maximum in any case being 0.03 per cent. Self-curing resin specimens processed in tin-foil substitute increased up to 0.2 per cent. As illustrated in Fig. 1, those specimens warped which were processed in a mold lined with tin foil on one side, tin-foil substitute on the other. The convex side was always the side processed against tin foil. The specimens shown in Fig. 1 are representative of the warpage occurring in heat-curing resins. Similar behavior was demonstrated using self-curing resins but the warpage was less pronounced. These results substantiate the findings of Sweeney[4-6] that the warpage of resin may be due to water sorption into the resin, through the tin-foil substitute during processing. Resin processed in a mold lined with tin-foil substitute is saturated with water during processing and, consequently, does not absorb more water during storage in water. When opposite sides of a specimen are processed against different mold linings, tin foil and tin-foil substitute, they will have different dimensional change behavior due to different water sorption characteristics. That more warpage occurred in heat-curing resin than in self-curing resin under such lining conditions is explained by the fact that the self-curing resins are not held at temperatures (above transition temperature) where water sorption occurs at the greatest rate.

Table II also illustrates the fact that self-curing resins do gain strength upon storage. The specimens used for the tests reported here were processed following the manufacturer's direction for 2½ hours, and the values reported indicate that polymerization continues beyond this time.

Table III shows this effect more clearly for two brands of self-curing denture base resins. The curing times of ½, 1, and 2 hours for one of the resins are within the range recommended by the manufacturer of that resin. It is evident from Tables II and III that sufficient curing time should be allowed for self-curing resins in order to secure good physical properties.

In Table IV, data are shown for transverse strength tests on a heat-curing resin using five different brands of tin-foil substitute as mold lining. It can be seen that there is some variation between the effects of various substitutes as indicated by this type of test. However, none of the substitutes used (including the one recommended by the manufacturer) resulted in values comparable to those obtained using tin foil as a mold liner.

## CONCLUSIONS

1. The use of tin-foil substitute as a mold liner for processing self-curing and heat-curing denture base resins results in a product with slightly less strength than when the resin is processed in a mold lined with tin foil.

2. Some difference was found between strength values for heat-cured resin specimens processed in molds lined with different brands of tin-foil substitutes.

3. The strength of self-curing denture base resins is decreased by a decrease in curing time. After 2½ hours curing time these materials do not exhibit full strength.

4. Self-curing and heat-curing resins show similar warpage habits after storage when processed in a mold lined with tin foil on one side and with tin-foil substitute on the other. Such warpage is more pronounced for heat-curing than for self-curing denture base resins. The warpage habits are explained by different water sorption characteristic of resin processed in contact with tin foil or with tin-foil substitute.

We wish to express our gratitude for the loan of a transverse testing machine from the Dental Materials Section of the National Bureau of Standards, Washington, D. C.

Acknowledgement is also due to Mr. Richard A. Beirl, junior dental student, who fabricated and performed transverse strength tests on a large number of specimens.

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# WAX, REFRACTORY INVESTMENTS AND RELATED SUBJECTS IN DENTAL TECHNOLOGY

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THIS ARTICLE contains various ideas and some new concepts which relate to the behavior of dental materials used routinely in dental practices.

## PHYSICS OF DENTURE WAXING AND INVESTING

Positive control of wax is assumed in technological literature, but it is seldom realized in practice. It is desirable, in some cases such as in denture work, to have wax with little or no volume change between its molten or plastic phase and its solid phase at room temperature. The wax used in the arrangement of teeth is used in considerable mass and is subjected to great temperature changes.

As an aid to analyzing the physical changes in the baseplate wax used for arranging teeth, I have put a thermometer into a ladle of melted wax and watched the heat rise while the ladle was kept in a flame. At about 350° F. the wax began to smoke quite freely. The thermometer had graduations to 350° F. and considerable stem above this. I let the heat rise as high as possible without damaging the instrument. Assuming that the rise of mercury in the remainder of the stem was still proportional to the heat, I found that even at 400° F. the wax did not flash or catch fire. At some undetermined point over 400° F., however, the wax did catch fire.

This means that in the articulation of teeth great heat may be applied to the wax with a hot spatula causing significant thermal expansion of the wax. The physical properties of inlay waxes are better known than those of baseplate waxes, and it has been reported that some inlay waxes expand as much as 1.3 per cent in the 25° F. range between mouth temperature and room temperature. Baseplate wax may have an even more significant coefficient of thermal expansion. If much heat is applied to the rim of wax used in arranging teeth, it is no wonder the teeth move out of occlusion when the mass of wax holding the teeth subsequently cools to room temperature.

The dentures may be waxed in the dental office and processed in a dental laboratory, and the wax dentures with the teeth in occlusion may make the trip to the laboratory at near zero temperatures. If the wax dentures make the trip attached to an articulator, the teeth will be completely out of occlusion.

What can be done about this? Refinement of occlusion may be done after the "setup" has been thoroughly cooled or warmed to room temperature by

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moving the teeth into occlusion, and securing them there with the minimum application of heat and molten wax. But, this is not the most significant part of the analysis. As every dentist knows, it is occlusion that is too high rather than too short that is the bane of denture technology. The wax used in the setup was spot heated so that temperature differentials are established throughout the baseplate wax, resulting in strains and elastic memory within the wax. Furthermore, the wax is pushed and pulled while the wax is in its plastic phase. This is the most drastic treatment to which wax may be subjected and leads to elastic memory, as subsequent tests will attest. Now, this very labile denture pattern is flasked and see what we do!

Each denture is invested first in the lower part of the flask. The investing material may, and usually does, embed a portion of the flange of the denture. With the rise of temperature produced by the exothermic heat of the set of the plaster, the denture pattern is heated. This heat is transmitted to the setup by conduction, and the wax pattern expands and distorts with the teeth moving in the only direction in which they are free to move—up. As soon as the plaster hardens, the wax denture pattern may or may not be tin-foiled, the upper half of the flask is pressed to place, a parting agent is applied, and the second half of the investing is completed. The lower half of the flask may still be quite warm from the exothermic heat of the previous pour of plaster. It warms the new plaster by contact, and with the new surge of exothermic heat, the wax is expanded still more. The processed denture captures and records the fully expanded denture pattern.

What can we do about this? Obvious corrections can be instituted once the physics are known, but if excellent compensation is not possible, there is always recourse to abrasives. The processed dentures should be remounted on the articulator with new records and spot ground into occlusion.

## PHYSICS OF INLAY WAXING AND INVESTING

Accuracy in the finished product, however, is not always served by holding the wax volume constant. Waxes, as used in the dental casting processes, would work better if they expanded in unison with mold expansion. Of all the clinical uses of wax in dental technology, its use in the casting process is most critical. Therefore, applying sciences to waxes in this field deserves our most serious thinking.

Our technological problem briefly outlined for direct inlay work is to prepare a wax facsimile of a prepared cavity in negative which, after a positive conversion, will yield a negative in gold accurate to $\pm 0.1$ or $\pm 0.2$ per cent.[1] Two negative and two positive conversions must take place before the gold negative of like accuracy is obtained by indirect methods. This requires a high order of accuracy in the procedures involved. Since shrinkages as well as expansions take place during the process, basically all that is needed is to employ the one against the other. While the problem lends itself to simple statement, analysis of the physical and chemical forces which play a part in the process brings up a very complex picture. Let us analyze these physical and chemical forces, and

observe where interference on our part is possible in order to control accuracy in the finished product.

Wax shrinkage, elastic memory, compressibility, and tensility directly affect casting accuracy. Indirectly, such factors as cavity size and shape (whether straight-walled or tapered) are represented in the pattern, and these too affect casting accuracy.

The wax pattern varies in size with temperature within a given grade, and the coefficient of thermal expansion varies with the composition of the wax. Most grades of inlay waxes shrink about 0.5 per cent between mouth temperature (95° F.) and room temperature (70° F.). Some waxes will undergo as much as 1.3 per cent linear change over the above temperature range.

In addition to dimensional change with temperature, the wax pattern possesses elastic memory. Like rubber and plastics, wax will tend to revert to its original form if it is worked or changed in shape from its original form. During the carving of an inlay pattern, the wax is subjected alternately to compression, tension, and shear. All of these acts produce strains in the wax of the carved pattern. The strains produced by working a thermoplastic medium are relieved in time by distortion of the finished product. This will occur at room temperature, or at temperatures colder than the forming temperature. For example, dentures which are processed from a blank of denture plastic at boiling or steam-pressure temperature distort over a period of time at mouth temperature. But, distortion of a strained body will occur much more rapidly and to a greater degree at an elevated temperature. Therefore, we can expect that wax patterns which have been formed from a blank of inlay wax will distort through release of pattern strains when removed from the cavity, especially if an investing method is used which employs heat as a compensating agent—warm water immersion in the hygroscopic investing technique.

Temperature changes producing distortion in the wax pattern may be positive, as in the case cited, or negative. Room temperature investment is applied to a pattern which may have been formed at mouth temperature or higher (in indirect technique) and cold air is blown upon the pattern with a chip blower to insure a bubble-free coating of the pattern with investment.

Elastic memory is generally induced in a body by changing its form from one configuration to another without melting. If melting of the thermoplastic medium takes place, the intermolecular strains are dissipated. In the case of wax pattern forming, melting the wax does not necessarily produce a strainless pattern. If the molten wax cools through a temperature gradient, it will pick up strains again. This must be evident to anyone who has carved a pattern over a metal die. If carving is done at room temperature which may be 70° F., the melted wax is much hotter—it may be 350° F. As it cools it will solidify first at the die because the metal of the die is acting like a radiator. When the outermost part cools, it shrinks and pulls the cooler part toward itself and away from the die. The wax may be made to conform by finger-tip pressure, but now the wax is being strained because its shape is being changed. A pattern formed under these conditions need only be removed from the die, set down on the bench for a few minutes, and replaced upon the die to exhibit clearly

the inaccuracy resulting from strain. Nevertheless, with suitable provision to mitigate the distortive influences mentioned, indirect patterns are best formed by using molten wax.[2]

## CHARACTERISTICS OF WAX

A press and two examples of extrusions of casting wax made with the press are shown in Fig. 1. Wax was melted and poured into the barrel of the syringe. When it cooled to its plastic phase, the wax was extruded through the jet. The wax was changed in shape in the process from its form and dimension in the barrel to that of the extrusion. One of the extrusions shown is made from a soft tacky wax (Kerr's green casting wax sheets) such as is used for partial denture castings, and the other is a standard inlay wax (Kerr's hard blue wax). Both extrusions are the same length (Fig. 2, *A*). The wax extrusions were

Fig. 1.

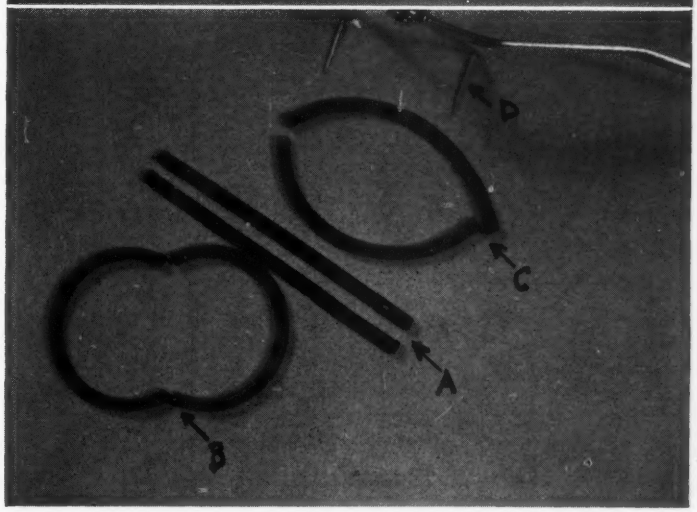



Fig. 2.

Fig. 1.—Press and two extrusions of wax.

Fig. 2.—*A*, Extrusions of soft and hard wax. *B*, Freshly molded extrusions. *C*, "Recovered" extrusions after twenty-four hours' immersion in a water bath at 110°F. *D*, Caliper denoting the dimension at the open end of the freshly molded extrusions. Note: The green wax specimen in every illustration is to the left or below its blue wax mate.

placed in a water bath at 110° F. together with a metal inlay ring. When the wax was thoroughly warmed, one each of the soft and hard wax extrusions were simultaneously wrapped around the inlay ring but free from contact with each other. They were then transferred to ice water until chilled, removed from the ring and replaced in the water bath at 110° F. The test was repeated several times. In Fig. 2, *B* are shown freshly prepared specimens and "recovered" specimens (Fig. 2, *C*). The freshly coiled and chilled specimens start to uncoil very promptly upon immersion in the 110° F. bath. The soft green wax "recovered" somewhat quicker and to a greater degree than the hard blue wax. After an interval of time, however, the blue wax recovered more than the green wax. In twenty-four hours the extrusions took the form shown in Fig. 2, *C*.

**Fig. 3.**

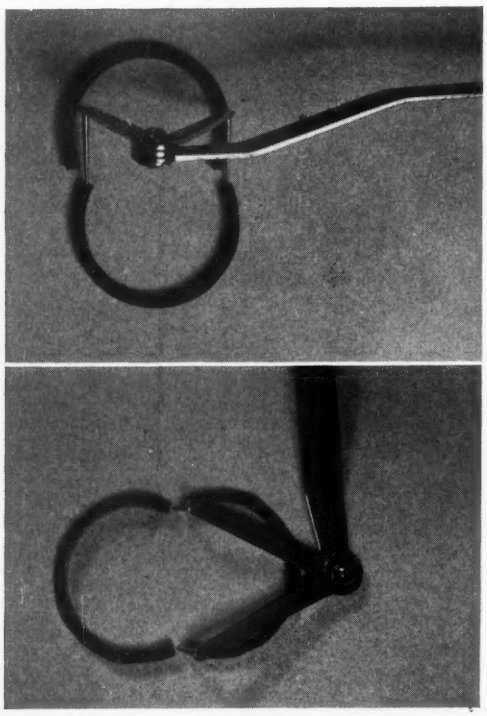


**Fig. 4.**

Fig. 3.—The molded extrusions after eight hours on the bench at room temperature.
Fig. 4.—Dimensional stability of "waxed up" rings after a three-hour immersion in a water bath at 110°F.

When the test was repeated, but chilling in water was avoided to temperatures cooler than room temperature, the extrusions took the form shown in Fig. 3. These extrusions were allowed to remain on the bench in a position of shelter from sun, air currents, etc., at room temperature for a period of eight hours. Rather little distortion took place. The blue wax uncoiled very little. The green wax retained the dimension of its open end almost exactly as shown by the caliper which was set before the extrusions were removed from the water bath.

Both extrusions slipped on and off the inlay ring with the "feel" of friction at this time.

Two wax rings were then formed of the green and blue waxes by melting and adapting the waxes to the inlay ring held at about 100° F. The wax rings were formed in a manner comparable to pattern forming over dies by the indirect technique. Melted wax was added in successive increments, worked and carved with a warm wax carver to simulate pattern forming. These ring patterns were cooled in room temperature water, and then immersed in a water bath at 110° F. Neither the blue nor the green wax ring distorted. After three hours' immersion, the green wax ring neither expanded nor shrank as shown by the caliper (Fig. 4).

These tests indicate that direct inlay patterns should not be used with investing techniques which employ heat. Indirect inlay patterns may be safely immersed in warm water baths. Soft waxes are recommended *for indirect work* because the pattern forming can be done at temperatures approximating the melting point of the wax, thus minimizing the effects of temperature gradients. The soft wax used in these tests is adhesive to a degree. This is an advantage in the art of pattern forming. It clings to the surface being restored, and the softness of the wax facilitates pushing or molding the stock under a warmed carver.

## PHYSICS OF THE CASTING PROCESS

Two shrinkages occur during the fabrication of an inlay, namely, wax shrinkage and casting shrinkage. The casting shrinkage takes place in three stages. First, there is a contraction of the molten gold from the initial heat to the solidification temperature, then a contraction during solidification, and finally the contraction from solidification to room temperature. The last is the significant change. The first two are amply compensated for by the flow of molten metal from the reservoir or button to the casting. For "B" type inlay golds, the significant contraction is about 1.4 per cent. This is less than the calculated shrinkage. Presumably the gold is stretched over the mold during its incipient solidification. If this view is taken, it may also be used to explain why bulky castings (especially thick-walled crowns) require more expansion for compensation than thin castings. The thin casting loses heat quickly to the mold in solidification so it captures the full dimension of the mold, but the thick casting retains its heat longer and crushes the mold as it cools.

Compensation for pattern shrinkage plus casting shrinkage may be done by (1) expanding the wax pattern, (2) expanding the refractory investment with heat, or (3) expanding the investment through additional hydration during its setting expansion—hygroscopic expansion. Critiques of the various investing methods employed to secure casting compensation emphasize that no single device enumerated above will yield sufficient expansion to offset the total of casting shrinkages. Either the thermal expansion or the hygroscopic expansion technique is most commonly used. As these techniques are used, both make use of thermal expansion as well as hygroscopic expansion. The hygroscopic technique merely emphasizes the degree of compensation by hydration, and usually uses a lower temperature to clear the mold of wax residue and gas. Wax expansion per se is inadequate

for total compensation, and is avoided because of the release of the pattern strains mentioned earlier. When wax expansion is employed, it is done with full knowledge of the hazards it entails. It is used in some investing procedures, not to secure mold expansion, but to return the pattern to the dimension at which it was formed.

## CHARACTERISTICS OF REFRACTORY INVESTMENTS

All dental refractory investments contain a gypsum binder. By chemical means, Van't Hoff[3] pointed out that reaction weights of plaster of Paris and water produce a hydrated mass of gypsum with a 7.1 per cent reduction in volume. This has been ably demonstrated by Mahler and Asgarzadeh[4] as it relates to inlay investments. When plaster of Paris is mixed with water, however, the hardened mass always has greater volume than the mixture itself. This increase in volume is referred to as "setting expansion," and if the plaster is permitted to harden under water, its setting expansion will be increased considerably. The shrinkage postulated by Van't Hoff, however, does occur. It is manifest in the countless tiny spaces or cell-inclusions within the mass of hardened plaster.

If the plaster of Paris is mixed with particles of sand as for dental refractory investments, or with various oxides or certain other finely divided substances, the hydration under water will be attended by still greater expansion. This augmented setting expansion is referred to as "hygroscopic expansion."

Without going into detailed theoretical reasons as to why the hygroscopic expansion occurs, it is known that hygroscopic expansion is characteristically weak in its initial set but gains power as crystallization progresses. A weak split inlay ring shown in Fig. 6, which has been thoroughly annealed by repeated heating, will start to spread when a pointed instrument or Vicat needle shows incipient setting. The split in the ring can be closed during the early stage of set, however, by finger pressure. Once significant crystallization occurs as determined by the Vicat test, the expansion is powerful. The split ring will open against the pressure of a dozen or more rubber bands twisted around the ring. The effect of hygroscopic expansion on a very stiff inner ring is shown in Fig. 11, *A* and *B*.

The foregoing and the following tests show (1) the distortion of the mold if restrained, and (2) the amount of the expansion. Fig. 5 shows the ordinary setting expansion of inlay hygroscopic investment (Beauty Cast) when it is poured directly into the ring without an asbestos liner, and permitted to harden on the bench. Note the fine crack which is a measure of the expansion. Figs. 6 and 7 show the effect of hardening under water. Fig. 8 shows the effect of an asbestos liner. The consistency of mix and procedure was as standardized for each of the tests as possible. In the last instance, since the asbestos liner provided space for lateral expansion and prevented a bond between the ring and the investment, the ring presented no restraint on the expanding refractory investment. The expanded refractory investment did not crack. This was only true, however, *provided* the asbestos liner extended from edge to edge of the ring. If the liner stopped short of either end, the ring opened just as much as if no liner was used.

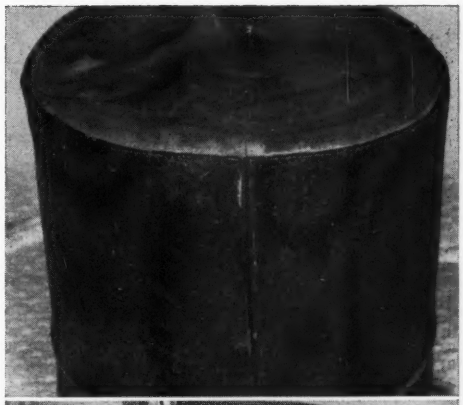


Fig. 5.

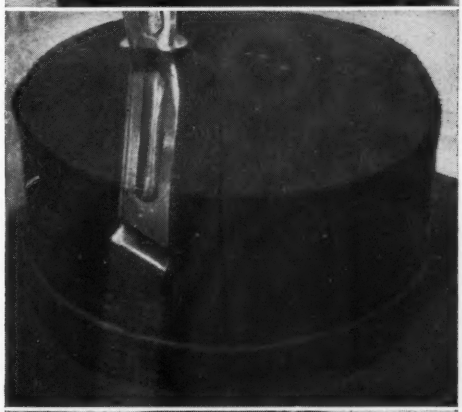


Fig. 6.

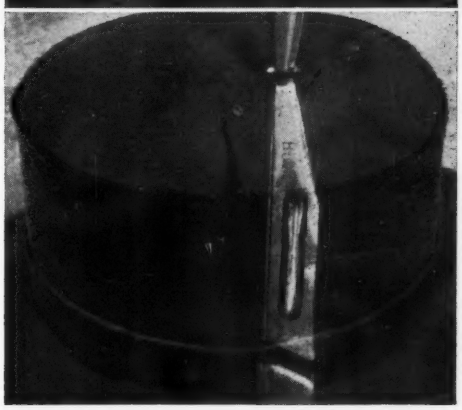


Fig. 7.

Fig. 5.—Setting expansion of hygroscopic investment at complete set on laboratory bench.[5] (Courtesy Journal of the American Dental Association.)

Fig. 6.—Setting expansion under water or "hygroscopic" expansion at partial set as shown by penetration of pointed scalpel. (The inverted image of the scalpel is a reflection from the water bath.[5]) (Courtesy Journal of the American Dental Association.)

Fig. 7.—Hygroscopic expansion at complete set.[5] (Courtesy Journal of the American Dental Association.)

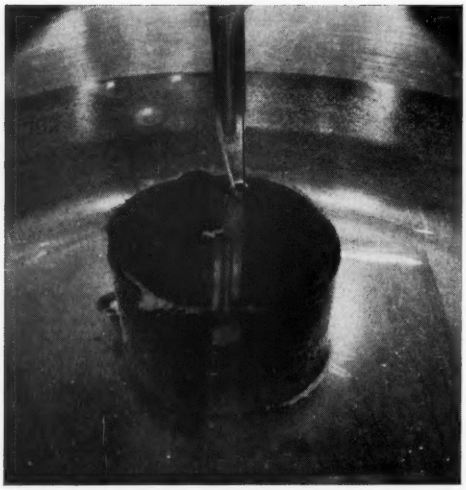
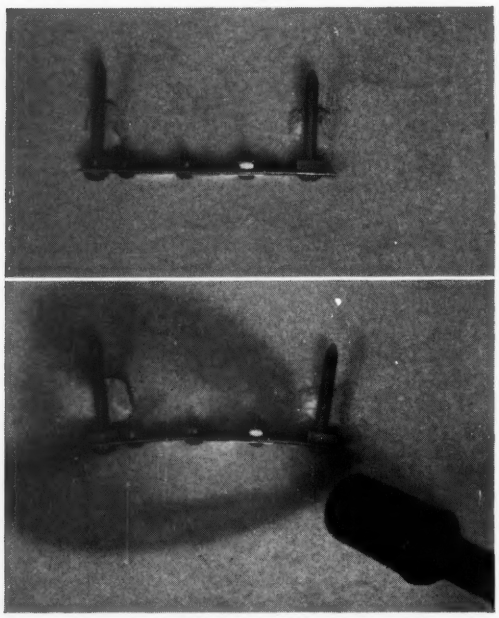


Fig. 8.—No distortion of the mold occurs when hygroscopic expansion takes place in a ring lined with asbestos.[5] (Courtesy Journal of the American Dental Association.)

*A.*



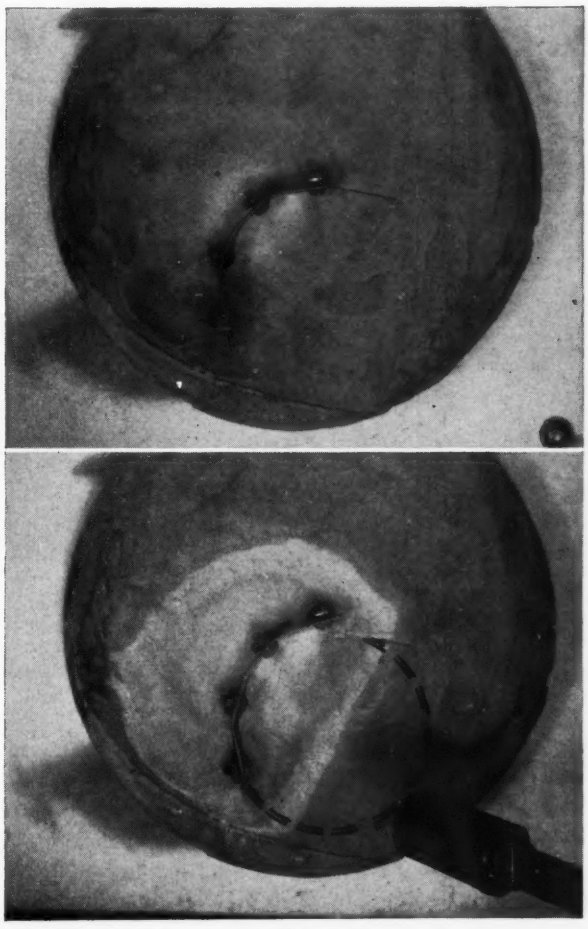
*B.*

Fig. 9.—*A,* A Copper-steel (annealed) "couple" before heating. The copper is the upper strip. *B,* The same "couple" when heated. The position of the camera remained unchanged for both exposures.

## WAX-INVESTMENT COUPLE

The behavior of a refractory investment in the split ring suggests the physics of a bimetallic "couple," such as is used for oven thermometers. When two pieces of metal of dissimilar coefficients of expansion are coupled or bolted together and subjected to heat, the couple will bend into a curved shape (Fig. 9). Fig. 9, *A* shows a copper-steel (annealed) couple in the cold state. The coefficient of thermal expansion of copper is $0.1678 \times 10^{-4}$ in the centigrade scale, annealed steel is $0.1095 \times 10^{-4}$. Fig. 9, *B* shows the characteristic arcing or bending when the couple is heated. If curved metal pieces are used with the metal of greater expansion on the inside, heat will straighten out or flatten the couple. Fig. 10, *A* shows such a couple in the cold state, and Fig. 10, *B* in the heated state. The

*A.*



*B.*

**Fig. 10.—*A*, A circular type of copper-steel (annealed) "couple" in the cold state. The copper strip is on the inside. *B*, The same "couple" when heated. It is only necessary to complete the circle with a compass and ink to demonstrate the likeness to the split ring-investment "couple" or the wax-investment "couple." The camera to subject position was unaltered for both exposures.**

expansion of dental refractory investment restrained by the split ring produces a situation analogous to that of the curved bimetal couple except that the hygroscopic expansion takes place without application of heat, and is limited largely to one element of the couple.

Fig. 11, *A* shows the effect of placing restraint within a mix of investment otherwise cushioned by an asbestos liner. We may view the split ring as a MOD pattern. Since MOD, three-quarter, and proximocclusal patterns offer similar restraint to the expanding investment, what is to prevent their being spread open like the ring shown in Fig. 11, *B*? During the early stages of set, at least, the patterns resist expansion of the investment. On a theoretical basis, it seems reasonable to assume that the proximocclusal type of pattern would be deformed by mesiodistal spreading.[5] Jorgensen[1] has tested the soundness of this premise using invested patterns and a microscopic sectioning technique. He concludes that tensility of the wax is a factor producing casting inaccuracy. The less restraint the wax affords to the expanding refractory investment, the smaller the error from this source.

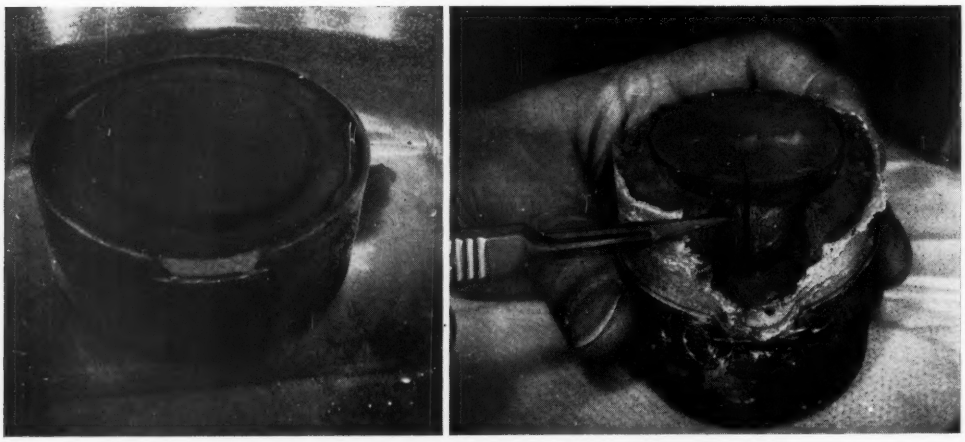


Fig. 11.—*A*, The "invested" split ring distorts the refractory investment within it. *B*, The ring is cut away.[5] (Courtesy Journal of the American Dental Association.)

## WAX COMPRESSIBILITY AND PATTERN SHAPES

Wax patterns are not exact transfers of the cavity dimensions. They differ dimensionally because of thermal shrinkage of the wax, and because saliva or a parting agent separates the wax from the cavity, and patterns of compound cavities are distortions. In addition to the differences between cavity and pattern dimensions just mentioned, compression creates still another difference. If a patient bites upon wax in forming an occlusal pattern, he is compressing the wax in the cavity much as rubber may be squeezed into a glass. When the wax is removed from the cavity, it expands just as the rubber will do in the analogy cited. The casting is made of the pattern in its expanded state. This accounts for the tightness of some direct inlays.

When wax is melted or otherwise conformed to a proximocclusal cavity, the wax solidifies and shrinks as it loses temperature. The dovetail portion shrinks in proportion to its size, and the box portion or flange does likewise. The shrinkage of the isthmus is, however, not proportionate. It is stretched between the dovetail on one side and the proximal flange on the other. Carving of the pattern further stretches and elongates this component of compound patterns. The elongation of the isthmus makes possible a measure of discrepancy in the other phases of the casting art, with the development of a usable fit in routine castings.

The fact that full crowns and occlusal inlays (but not direct occlusal patterns) usually require the maximum expansion to secure a desirable fit attests to the accuracy of the premise. The occlusal pattern made from molten wax, without compression incorporates the shrinkage of a considerable mass of wax, and it is smaller by the thickness of parting agent. The wax of the full crown pattern is stretched over the die as it solidifies and cools. When it is completely cooled, the pattern grasps the die much as a metal tire, when heated and put to place over the framework of a wooden wheel, grasps the wheel. When the jacket pattern is removed from the die, it contracts, thus necessitating maximum expansion to compensate for wax and casting shrinkages.

All castings, except full crowns, made from patterns drawn from a die are loose as compared with castings made from refractory casts of prepared cavities. As would be expected, just the reverse is true of the full crown. These statements may be verified by making impressions of prepared cavities in Permlastic, making refractory casts in these impressions, and waxing to the refractory casts, provided suitable precautions are taken to standardize all procedure.

## SOLDERING

"Couple" effect is responsible for soldering inaccuracies. If the pontics and abutments of an invested bridge touch when they are heated on the refractory investment jig, their expansion will be greater than that of the supporting investment, and the assembly will be changed from a linear arrangement of the parts. Since the gold alloy expands more than the refractory investment, interproximal contact of the parts to be soldered may produce an expanded arc which will push the pontic upward. It is not uncommon to find the pontic out of contact with the ridge in the resulting solder assembly. Distortion also occurs immediately following the solidification of the first soldered joint. All subsequent soldering on the same jig is subject to error due to the cooling of the gold investment "couple."

Since the error varies directly as the mass of refractory investment employed, soldering should be done one joint at a time with the barest minimum of the investment. The bulk of metal should not be incorporated in the investment. Also, since the expansion is radial in character, where spot welding is not possible and a refractory investment jig is necessary, the joint to be soldered should be in the center of the investment. The investment should be dried but not preheated, and soldering should be done as quickly as possible with a tiny acetylene-compressed air torch. This should minimize the spreading of the pieces to be assembled.

## CONCLUSION

Methods of control over the physical properties of wax suggest themselves, once the physics involved are known. The coefficient of expansion of wax, its elastic memory, compressibility, and tensility are directly related to fabricational accuracy of the finished prosthesis. Indirectly related are cavity size and type. The behavior of wax in a refractory investment or metal in a refractory investment is like that of two metals of differing expansions united and subjected to heat.

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# AN ANALYSIS OF CURRENT PRACTICES IN MOUTH REHABILITATION

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THE LAST THREE decades have witnessed tremendous progress in all fields of dentistry. All current experimentation and research in various branches of dentistry is inspired by a common purpose, i.e., to develop the most effective program of oral health service for curing as well as preventing *disease*. However, the road leading to this is long and thorny, filled with a history of trial, error, and adjustment. In this great effort for the treatment and prevention of dental disease, many earnest investigators and clinicians have developed many procedures based upon a multitude of theoretic considerations. The final judge of the validity of some of these theories is clinical experience, which is indeed a stern arbiter. One of the clinical procedures which has gained popularity among our colleagues in the last decade is the practice of "mouth rehabilitation" and associated with it the frequent concomitant practice of "bite-raising." The dental profession has now gained sufficient experience to examine its efforts and to critically review the procedures in mouth rehabilitation and "bite-raising," from both the clinical and the basic science frames of reference. It is the purpose of this article to examine these clinical practices and the theoretic principles which guide them.

It is appropriate before developing the discussion to define mouth rehabilitation and bite-raising.

*Mouth Rehabilitation.*—In the traditional, broad sense, mouth rehabilitation is the major clinical activity of the practice of dentistry in which we are all daily engaged. It implies the employment of all the diagnostic, therapeutic, and restorative procedures at our command for the treatment and prevention of dental disease. All dentists practice mouth rehabilitation to a greater or lesser degree when they perform preventive, surgical, or restorative procedures.

In the narrower, more recently acquired sense, the term mouth rehabilitation is used to indicate extensive and intensive restorative procedures in which the occlusal plane is modified in many aspects in order to accomplish "equilibration." The modification of the plane is characterized by: (1) the spirit of full coverage, (2) the use of multiple crowns, (3) the multiple splinting of teeth, (4) the all-too-frequent alteration of the vertical dimension of occlusion (bite-raising), (5) modification of the arch form by positioning the crown portion of the teeth to the labial or lingual direction, and (6) the employment of various procedures for the "repositioning" of the mandible.

These modifications to the arch form and the occlusal plane are motivated by several factors: (1) improvement in esthetics, (2) restoration of occlusal function, and (3) in the interests of relieving temporomandibular joint dysfunction.

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*"Bite-Raising".*—Associated with this latter concept of mouth rehabilitation is the practice of "bite-raising" in which the clinical crowns, frequently involved in a multiple splinting procedure, are prepared so as to increase the vertical dimension of occlusion, i.e., the crowns are restored so that the clinical crowns have been increased in length beyond their length before the restorative procedure was initiated. The effects of this increase in crown length are mandibular over-opening and a reduction or complete obliteration of the interocclusal rest space (free-way space).

It is the purpose of this article to discuss the principles and the consequences of the clinical practice of "bite-raising" with emphasis in the following areas: (1) the interocclusal rest space, (2) the temporomandibular joint, (3) the restorative practices of full coverage and excessive splinting, and (4) all-too-frequent removal of the pulps of teeth.

The tremendous drive and impetus for "bite-raising" procedures are spurred on by two important factors:

1. The accelerated technique for the preparation of teeth for full coverage.
2. The passion and inordinate longing for esthetics in dental restorative procedures.

If we exercise judicious moderation, both considerations are most commendable. However, the frequent concomitants of these procedures, (1) sacrificing the free-way space, and (2) the removal of the dental pulps for esthetics and technological speed, are both ill-advised.

## THE PHILOSOPHIC BASIS FOR MOUTH REHABILITATION

It is interesting to recall the two schools of thought dominating our approach to diagnosis and treatment planning of dental deformities in the last few decades. The older one conceived the condyle path as observed on the skulls as the main determining factor for the establishment of the vertical dimension, cusp-height, and compensating curve.

The second school of thought holds that since the posterior teeth are in closer proximity to the incisal guidance than to the temporomandibular joint, the incisal guidance is the determining factor in the establishment of the vertical dimension, cusp height, and compensating curve. Both schools of thought are earnest and conscientious in their effort to promote and maintain oral health by means of their respective and diametrically opposite restorative procedures. Conflicting claims of superiority are advanced by each of these groups. Each one contends that its method of treatment alone will restore the masticatory mechanism to health in harmony with the biologic requirements and interests of the patient.

## THE CONDYLE PATH CONCEPT

A careful and objective appraisal of the old and newer trends in mouth rehabilitation reveals that in spite of the widespread usage of such terms as "biologic" and "biomechanical" in the literature on this subject, the procedures prevailing are still mechanistic and technologic in nature. For example, the following is recommended in the literature by the school of thought dominated by the condyle path concept: To measure the depth of the glenoid fossa, the shape, size, and form of the condyle, and the inclination of the eminentia articularis *on*

*skulls,* and on this basis alone prescribe specifications for "anatomic articulators." This is obviously unscientific. The following considerations are indicated for a truly biologic approach:

1. A study of the topography, morphology, and histology of all the soft tissues that participate in the architectural design of the temporomandibular joint should be made.

2. A careful analysis and appraisal of the physiologic function of the temporomandibular joint in health should be correlated and integrated with the anatomic architecture of the structures involved.

3. The knowledge derived is to be applied in everyday clinical practice by studying the various temporomandibular joint syndromes, by contrast with what we consider function in health.

4. This, in turn, is to be subjected to an examination by the "third eye"—the roentgenograms. The latter will aid us in our study of the various postural positions the condyles occupy in their relations to the glenoid fossae.

A broad understanding of all these features and their integration will make possible a comprehensive diagnosis relating the anterior elements of occlusion (occlusion of the teeth) and the posterior elements of occlusion (temporomandibular joint articulation). The morphology, per se, of the bony structures of the temporomandibular joint cannot, and should not, be utilized as a basis for concepts and conceptual schemes of the physiology of this joint. However, articulators were and are now built to reproduce the *geometric inclination* of the posterior wall of the eminentia articularis (condyle path). This is a typical example of mechanistic dentistry with its tendency to translate the most delicate and most complicated physiologic phenomena into simple mechanics.

### THE INCISAL GUIDANCE CONCEPT

The second school of thought, in my opinion, goes even further. Its proponents advocate primary consideration for the incisal guidance in mouth rehabilitation procedures, on the basis that the physiology of the temporomandibular joint will adjust and adapt itself to the incisal guidance. This means that we arbitrarily create adverse physiologic conditions in an organ in the hope that Mother Nature will take care of herself. A joint concerned with mastication, deglutition, phonetics, esthetics, postural position of the head and neck and an array of neuromuscular, vasomotor, and psychologic influences is thus jeopardized for the sake of a preconceived, arbitrary concept of tooth guidance. Such a concept is highly personalized, because, in mouth rehabilitation or "bite-raising" procedures, the amount to which the vertical dimension is increased depends largely upon the operator's individual judgment. What is more, the operator may be misguided in his work by the old concept that an arbitrary 2 to 3 mm. free-way space constitutes a physiological rest-position of the mandible. Thus, to rely upon the incisal guidance as the sole guiding spirit in "bite-raising" procedures is to imply that vertical overlaps constitute abnormalities. But then, the vast majority of human dentitions are abnormal. It is true that the incisal guidance, in a patient with an excessively deep vertical overlap, interferes to some extent with wide-range lateral movements and the masticatory stroke, but it should be remembered that at the age at which patients seek mouth rehabilitation, their

dentitions are past the formative stage. In most instances these patients are in the retrogressive stage of their life span—a time least favorable for radical "bite-raising" procedures. If the vertical overlap is to be reduced, it should be achieved mainly at the expense of reshaping the upper and lower anterior teeth, and not solely by "bite-raising." The word reshaping is used here in its broad sense. It implies a modification of the teeth in size, shape, form, and inclination which, when thoughtfully and intelligently executed, provides the needed freedom of mandibular excursions. A natural dentition with a deep vertical overlap of the anterior teeth need not be considered definitely abnormal in spite of the fact that statistical averages may place it in that category. This type of occlusion may not conform to our concept of an average occlusion, and yet it may function properly. Statistical averages cannot be used as therapeutic agents, and each patient should be diagnosed on the individual merits of function and not on the basis of normal or abnormal static intercuspation.

This raises the question: What is our concept of a normal occlusion or a normal dentition? The dimension of the jaws and teeth are different in different individuals, and cannot be standardized under one particular measurement. The same holds true for the free-way space (interocclusal rest space). The same reasoning applies to the size, shape, and form of individual faces. There are no two exactly alike. Yet we speak of *normal* and *abnormal* faces. It would be more appropriate to speak about more pleasing and less pleasing faces. But even this would be subject to great individual variations in the judges' esthetic tastes. How then can we established a definite concept of normal or abnormal vertical dimensions on the basis of the vertical overlap of the anterior teeth (incisal guidance) with complete disregard of the *status of the condyle in the glenoid fossa* and the *particular status of function of the individual masticatory mechanism.* There is no objection to the use of the incisal guidance as a starting point when it is considered from a mean or average viewpoint. However, the diagnosis of proper or improper function must be confined to the particular individual under treatment and not to an arbitrary concept of a normal or abnormal incisal guidance.

## FACTORS OF GROWTH AND DEVELOPMENT

The size and biologic pattern of a person's interocclusal rest-space are the result of the pattern of growth and development of the head and face. The pattern of development, in turn, is conditioned by the inviolable hereditary tendencies and the sum total of influences and experiences exerted upon the individual by his particular environmental milieu. Therefore, the interocclusal rest-space is to be regarded as an anatomic entity with its definite and characteristic physiologic function in mastication and phonetics, just as the isthmus of the fauces and the nasal passages are, respectively, for deglutition and respiration.

Obviously, we are in need of a broader and more scientific approach to the study of the problem of occlusion and the related free-way space and temporomandibular joint. We should make an earnest attempt to correlate and integrate the developmental anatomy of all the structures of the head and neck with the masticatory mechanism before approaching our main objective, i.e., function. By correlating structure and function, an entirely new concept is formed. We realize that we cannot speak of normal function any more than we can talk about normal anatomy or normal occlusion. What is normal for one individual may be ab-

normal for another. There are various *degrees of malfunction* and various *degrees of good function* — each corresponding to various patterns of developmental anatomy. Of course, the latter is also greatly influenced by genetic and phylogenetic factors. At the same time, we are cognizant of the tremendous role that a particular and peculiar process of development plays in the maintenance of a given status of homeostasis.

Nor can we accept the incisal guidance theory as the sole diagnostic criterion for rehabilitation and re-establishment of new occlusal relations. The incisal guidance is accepted as the standard bearer for "bite-raising" because it is nearer to the posterior teeth than the temporomandibular joint. This only serves to strengthen our feeling that dentistry has great difficulty in extricating itself from the mechanistic stage. The connotation of the words *distance* and *space* in physics, as used, for example, by the engineer in the construction of a fence, becomes meaningless when applied as a biologic criterion. The engineer, in designing a fence, can measure the exact strength of the cement that serves as the foundation, as well as the height and leverage of the posts, and on that basis he can calculate the optimum distance between the posts. Can we afford to use this mechanical approach for measuring the most complex biologic and neuromuscular phenomena of the masticatory mechanism? My belief is that we cannot. Various individuals manifest different reactions to the same outside influences. This depends upon the different physiologic limitations of tolerance in different individuals.

## FACTORS OF PHYSIOLOGIC-PATHOLOGIC BALANCE

In "bite-raising" procedures two phenomena are observed. When the "bite-raising" exceeds the physiologic limits of tissue tolerance, acute disease will immediately set in, either in the periodontal structures, or in the temporomandibular joint structures, or in both. If the physiologic adaptive capacities have not been exceeded, but overburdened and strained in various degrees, disease of a chronic nature will ensue as a consequence. The course of the disease and its pathologic pattern will depend upon the severity of the strain and the capacity of the tissues to mobilize temporary means of defense. This is clearly observed in the course of diseases of the heart, kidneys, and eyes. When these organs are subjected to severe strain, but without abrupt overpowering of their physiologic limits of tolerance, they develop a defense mechanism of a pathologic pattern with the obvious objective of fighting a delaying action. A coronary thrombosis will result either in death or in a gradual enlargement of the heart. Similar reactions are manifest in the periodontal structures and the temporomandibular joint mechanism.

It is for this reason that I feel that great caution should be exercised before any "bite-raising" procedure is undertaken. Situations with definite, clear-cut indications for "bite-raising" are very rare in the hands of conservative operators. Conservatism is motivated by a careful study of cause and effect in diagnosis and planning of treatment.

Let us consider a hypothetical case of a middle-aged patient whose occlusion has undergone considerable attrition. The overclosure observed by the operator may not represent a pathologic condition. Instead, it may be a slow and gradual

physiologic process of readaptation to a certain pattern of development and function of the muscles of mastication. Either the muscles of mastication have proved too powerful for the resistance of the enamel, or the patient's pattern of occlusion was endowed with a wider than usual lateral swing of the mandible, which is a frequent cause of attrition. If, on the other hand, bruxism or bruxomania constiture the causative factors of attrition, "bite-raising" will serve only to aggravate the existing condition.

### THE WIDE RANGE OF NORMALCY

It is clear that the range of mandibular movements and their corresponding effects within physiologic limits of tolerance are tremendous. So much so that attrition, per se, in individuals past middle age should not be looked upon as an abnormality requiring "bite-raising" or mouth rehabilitation as long as the dentition functions properly. It should rather be regarded as nature's way of readaptation to new environmental conditions of function. The same is true of some cases diagnosed as mandibular overclosures with periodontal backgrounds. They need not necessarily be corrected by the drastic means of "bite-raising," which frequently prove more detrimental than useful. There are safer, conservative, more rational, and more effective therapeutic procedures that will better serve the interests of our patients: (1) judicious and careful equilibration of the occlusion (without aiming at perfect balanced occlusion in the natural dentition); (2) augmenting the resistance of the periodontal structures by means of massage and scaling; (3) elimination of the periodontal pockets by means of conservative or surgical procedures; (4) changing to a harder or softer consistency of the diet depending upon the etiologic factors in the breakdown of the periodontal structures, i.e., understimulation or overstimulation; (5) improving the nutrition and metabolic processes of the patient; (6) relieving the effects of bad habits by means of judicious physical exercises and psychotherapy.

Consultation with the periodontist is most advisable in these instances, and will probably have the effect of greatly reducing the number of "bite-raising" cases. Recourse to "bite-raising" under the "new-look" name of "mouth rehabilitation" has become so widespread and has resulted in so many failures that caution must be re-enforced with a large measure of outright pessimism toward this trend in present-day dentistry. This judgment is based upon the study of our literature, the observation of numerous patients so "rehabilitated," and upon my own investigations in the field of the free-way space[1] and the temporomandibular function.[2, 3]

My studies of the free-way space (interocclusal rest space) have shown that it ranges between 1.5 and 8 mm., and that it is an integral part of the masticatory mechanism, and in a harmonious relationship with the adjacent and associated structures. Whatever its physiologic status, it should be preserved and maintained. Reducing or augmenting the free-way space in natural dentitions will, in most instances, interfere with proper function of the masticatory mechanism and will eventually induce disease. Excessive increase of vertical dimensions in complete denture prosthesis leads to rapid resorption of the alveolar process until the physiologic interocclusal rest space is re-established. The musculature is dominant and will struggle for the maintenance of its tonus in a state of equili-

brium. Mershon[4] expressed the same view many years ago: "Any effort to change the operation of this joint places a strain on the muscles of mastication; in order that this be relieved, the adaptable alveolar bone resorbs until the joint is once more in its normal position. Muscle is dominant; it cannot shorten or lengthen and it cannot remain under tension indefinitely. Therefore, the other tissues change and adapt themselves until the muscles are relieved of all strain."

### "BITE-RAISING" MAY INITIATE PATHOLOGY

"Bite-raising" may interfere with the naturally established pattern of the primary function of the muscles of mastication and expression. "Bite-raising" may also effect a change in the mutual relationship of these muscles to the natural dentition as well as to the artificial dentures. It will have the same adverse effect upon the temporomandibular joint structures. "Occlusal reconstruction" or "restoration of the occlusion" are meaningful terms if they are not used merely as a substitute for the term "bite-raising." Reconstruction or restoration of an occlusion implies raising the level of teeth that are in infraversion, reducing the level of teeth that are in supraversion, with the interocclusal rest space and the tonicity of the muscles of mastication remaining at their "status quo" level.

I will differentiate between the "status quo" of the muscles of mastication and the temporomandibular joint ligaments, respectively, when the mandible is at rest and when it is raised to effect intercuspation of the teeth. In the first instance, at rest, the muscles of mastication and the ligaments are in their full *resting length* in a state of physiologic muscle tone. In the second instance, when the teeth effect contact, the temporal, masseter, and internal pterygoid muscles are in a state of hypertonicity while the temporomandibular joint ligaments are loose and wrinkled and in a state of hypotonic rest.

Thus, *muscle tonus* is the point of equilibrium between the smallest gradations of hyper- and hypotonicity and could be defined as follows: It is a particular and peculiar state of *muscular activity* which maintains the body in a state of equilibrium. It is not productive activity in a strict sense, it is rather a state of activity that keeps the muscles vigilantly ready for instant action.

Perry[5] expresses it succinctly when he states: "The activity called tonus can be compared to the idling of an automobile engine—it is in a state of readiness for instant activity maintained with a minimal expenditure of energy."

We should endeavor to maintain the muscles of mastication and the temporomandibular joint structures in this state of equilibrium at all times. Nature has endowed these structures with distinct features for specific function. Thus we find that when the teeth are in centric occlusion, the temporomandibular joint capsule manifests folds and wrinkles. We have good reasons to believe that these wrinkles have been provided by nature to enable the mandible to assume its physiologic rest position. If the folds and wrinkles were not present with the centric intercuspation of the teeth, then the capsule would have to become *distended* for the transition from the active to the passive vertical dimension, i.e., the physiologic rest position. With a *distended* and *strained* capsule there can be no physiologic *rest* position. This is precisely what happens with our "bite-raising" procedures. We obliterate the capsular wrinkles with the obliteration of the interocclusal rest space. The muscles of mastication as well as the

temporomandibular joint structures are thus placed in a state of tension from which they find it difficult to recover. The indiscriminate obliteration of the interocclusal rest space is usually followed by traumatic occlusion. The latter, as defined by Orban,[6] coincides with our own concept on this subject: "We can define traumatic occlusion as an occlusion in which changes of the functional relationship are commencing too rapidly for physiologic readaptation, causing pathologic changes which ultimately will also lead to functional readaptation, but this pathologic readaptation is progressing in a stormy manner."

The more the vertical dimension is increased, the less favorable will be the resulting action of the muscular forces upon all the structures concerned. Indeed, the more the vertical dimension of occlusion is increased, the greater the deviation from parallelism of the opposing alvolar ridges. This means that when a bolus of food is introduced between the occlusal surfaces of teeth with an excessive vertical dimension, the mandible assumes a still greater obtuse relationship to the maxilla. Forces acting under the unfavorably changed mechanical conditions will have simultaneously an adverse effect upon their direction, distribution, and magnitude. Add to this the disharmony thus created between the plane of occlusion and the muscles of mastication and the corresponding displacement of the condyles in their glenoid fossae, and we get a clear picture of the hazards involved in excessive "bite-raising." This pertains to all restorative procedures of the masticatory mechanism including complete dentures.

Nagle[7] puts it this way: "As already brought out, the ideal relation between denture supporting areas is the horizontal and that the desired direction of force is at a right angle to these areas because it is a direct force. According to these dictates, the occlusal plane should be parallel to the alveolar denture supporting areas, or as nearly so as possible. There are considerations which must be recognized if the importance of this maintenance of direct forces is to be fully understood. The first of these is the position of the occlusal plane as related to vertical dimension. If the vertical relation is open, there will be an incline of the mandibular supporting base. This will cause a tendency for forward slipping of the mandibular denture with the introduction of traumatic forces which are not desirable for denture comfort. Open vertical dimension should, therefore, be avoided, with the error (if at all) on the 'closed' side."

There are many other arguments against "bite-raising" procedures. Outstanding among them is the unfavorable change in crown-root ratio that it all too frequently produces. I believe that it is the concensus of our leading periodontists and orthodontists that to augment the crown-root ratio in a healthy tooth frequently means to inoculate it with periodontal disease. But when this procedure is used on a tooth already afflicted by periodontoclasia, it is tantamount to a fatal blow for that tooth from a periodontal standpoint. This in itself should be sufficient to make us more vigilant and circumspect.

### EXCESS USE OF MULTIPLE SPLINTING

Some "mouth rehabilitation" enthusiasts splint six, eight, ten, or more adjacent teeth with a view to retaining teeth that have long outlived their usefulness and may present definite potential hazards to the patient's health. It has been pointed

out by leading periodontists that neglected periodontal disease with deep and wide-open periodontal pockets carries with it great potentialities of focal infection Yet, we are trying to save such teeth by multiple splinting which, in turn, makes further treatment of these teeth by the periodontist difficult because of the difficulty of access to the pockets. I have observed too many patients so "rehabilitated" with appalling rampant infection around the hard and soft structures of the teeth. As members of a fine healing profession, we cannot close our eyes to the adoption of such misguided principles as therapeutic measures.

### EXCESSIVE USE OF FULL COVERAGE

Three to four decades ago the profession was engaged in "prevention" of caries by means of multiple full coverage of healthy teeth by swaged crowns. Today, we are using cast veneer crowns for the same purpose. This is not to be interpreted as implying that I identify the veneer crown of today with the swaged crown of several decades ago. Certainly not; the veneer crown is incomparably superior to its predecessor; it is a masterpiece by comparison. But let us not abuse our magnificent technologic advances to a point of disregarding fundamental biologic principles. Where eight or ten adjacent teeth (particularly when some or all of them are in labio- or buccoversion) are being prepared with lightning speed for veneer crowns, damage to the dental pulp is bound to occur in a vast number of teeth. The required parallelism and reciprocity of the various surfaces of these adjacent multiple preparations—*conditio sine qua non* for the ease of insertion of the final restoration—brings us into dangerous proximity to the dental pulp organ. In addition, the lightning-like rapidity with which the stones and discs revolve around these teeth may have their ill effect upon the circulation of the blood in the dental pulps. This is not to deny that some outstanding men in the field of mouth rehabilitation are getting excellent clinical results by these procedures; but individual and scattered favorable clinical results do not make a procedure sound for universal acceptance.

However, multiple splinting of teeth with infected and necrotic periodontal pockets is not the cure of such conditions, and full coverage of the teeth by veneer crowns is not preventive medicine for dental decay. Both periodontal disease and dental decay are pathologic conditions caused by a disturbance of normal biologic processes. To cure or prevent such conditions, their causative factors must be removed. Therefore, we are in need of *extensive and intensive biologic reasearch* if we are to direct the progress of dentistry along the proper channels.

### INJUDICIOUS TREATMENT PRODUCES ACTIVE PATHOLOGY

The most important single thing we are to bear in mind in health service is never to inflict injury on the patient. The temporomandibular joint is a very complex and delicate structure. Any stress or strain brought to bear upon this joint by injudicious "bite-raising" procedures tends to disorganize the blood and lymph circulation, and produces in it a chronic and degenerative disease. In former years, temporomandibular joint pain was attributed exclusively to pressure exerted by the mandibular condyle upon the chorda tympani and the auriculotemporal nerve in instances of even slight mandibular overclosure. This was due, in part, to a misconception prevailing at the time that the excursions of the condyle extend into all parts of the glenoid fossa. It has been established that the function

of the mandibular condyles is definitely limited to the confines of the anterior part of the glenoid fossa—the mandibular cavity (Sicher[8, 9]).

Slight mandibular overclosures in individuals past middle age may be considered as physiologic a phenomenon as the appearance of gray hair at this age, or a reduction in stature with old age resulting from flattening of the intervertebral cartilages. Furthermore, it is difficult to see how even the more or less advanced mandibular overclosures can press directly upon the chorda tympani and the auriculotemporal nerve. Temporomandibular joint roentgenograms secured by the traditional method, and those obtained by our own method of unstrained prosthetic recordings, as well as those secured by the cinefluorographic method, all indicate that the mandibular condyles remain confined in instances of mandibular overclosure to the mandibular cavity.

## PHYSIOLOGIC CONSIDERATIONS IN CHANGING VERTICAL DIMENSION

Other syndromes, following mouth rehabilitation with excessive overopening of the mandible, cannot be ascribed to one particular affected structure, but rather to a number of structures that become involved in a state of tension. They are the vasomotor, neurogenic, myogenic, and psychogenic factors in a state of interdependence and interaction. They manifest a combined reaction to a disturbed function. It is true that great variations in the dimension of the interocclusal rest space are observed (1.5 to 8 mm.) within physiologic limits. But it is also true that when this rest space is only partly obliterated, it results in disturbed function of the temporomandibular joint structures. We seem to lose sight of the fact that physiologic occlusal contact of the maxillary and mandibular teeth is not only a primary function in mastication, but it is also essential for the propulsion of the food into the pharynx (deglutition). With mandibular overopening of various degrees, corresponding degrees of tension are also created in the temporomandibular joint structures, muscles of mastication, and the circulation and innervation mechanisms during the process of deglutition.

In the healing arts of medicine and dentistry, all our efforts should be channeled in the direction of cooperating with nature, rather than to disturb its physiologic equilibrium.[10] If tension is induced in the muscles of mastication by excessive "bite-raising" procedures, these muscles will resist until their physiologic tonicity is re-established. To advocate extensive "bite-raising" procedures on the basis of labeling the temporomandibular joint as a "universal joint" with capacities for "universal adaptation" is equivalent to seeking a formula for reconciling irreconcilables.

## SUMMARY AND CONCLUSIONS

1. There is a definite trend in our profession to excessive "bite-raising" procedures on the assumption this will *prevent* temporomandibular joint syndromes. The opposite is true. This practice all too frequently induces disease instead of preventing it.

2. The patients' insistent request and our own overenthusiasm for esthetics are probably the most important causes for the widespread practice of "bite-raising." There is no doubt that esthetic values in dentistry have greatly contributed to the happiness and mental health of our people. We should strive to the utmost for esthetic values in all branches of restorative dentistry. However, here too,

as in all human action, moderation is a fundamental commandment. "Bite-raising" should never be done at the expense of the health of the dental pulps, periodontal structures, or the temporomandibular joint. Unreasonable reduction or complete obliteration of the interocclusal rest space (free-way space) is definitely harmful to the temporomandibular joint and associated structures. Frequently, it leads to chronic and degenerative disease of these structures associated with radiation of pain in the oral cavity and various parts of the head and face.

3. *Excessive "bite-raising"* with multiple splinting based on the incisal guidance conceptual scheme is unsound from a biologic standpoint. This scheme presupposes that the mechanically organized and newly established tooth guidances will lead the muscles of mastication and the temporomandibular joint structures to adapt themselves to the radically altered environmental conditions. In reality, the reverse is true. If readaptation does take place, it is in the direction of pathologic readaptation.

4. Many of the so-called mandibular overclosures which are mistakenly considered as "collapsed bites" are in reality not pathologic in nature. In individuals past middle life, this tendency in the direction of a reduction of the vertical dimension may be considered, in many instances, to be within physiologic limits of tolerance. However, it should be slowed down or completely arrested, in some instances, by properly instituted therapeutic procedures. Good operative dentistry, combined with conservative equilibration of the occlusion and treatment of the periodontal structures, is the treatment of choice. In individuals past middle age, a slight mandibular overclosure is always to be preferred to "bite-raising." It should be considered basic that we cannot encroach upon the integrity of the free-way space (interocclusal rest space). This relates to all phases of restorative procedures, including complete dentures, removable partial dentures, and fixed partial dentures.

5. Mouth rehabilitation is dentistry, but not a "specialty" in dentistry. Every earnest dentist is engaged in a mouth rehabilitation service irrespective of the particular operation he is performing on his patient, be it a prophylaxis, insertion of a partial denture, an MOD inlay, or an amalgam filling.

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# THE RELATION OF NEW KNOWLEDGE OF THE GINGIVA TO CROWN AND BRIDGE PROCEDURES

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IT IS THE PURPOSE of this article to discuss the relation of certain recent research on the gingiva to clinical practice of crown and bridge prosthodontics. The investigations cited present new viewpoints regarding the morphology and function of the marginal gingiva in health and disease. The application of these contributions to treatment plan, operative techniques, and home care is described.

## REVIEW OF LITERATURE

Recent investigations by Waerhaug[1] reveal the need for complete re-evaluation of accepted theories concerning the relation of the marginal gingiva to the tooth. He says the histologic concept of the gingival pocket described by Gottlieb[2] does not coincide with the clinical pocket, and that it is of great significance theoretically and practically, in order to distinguish between the physiologic and pathologic. It is also pointed out that Gottlieb's[3] conclusions concerning an organic epithelial attachment to enamel are based solely on microscopic evidence. Consequently Waerhaug performed a series of experiments to illuminate the problem from as many sides as possible. Conclusions drawn from his comprehensive studies indicate that no firm organic union exists between the free gingiva and tooth surface, but that Black's[4] concept is, on the whole, correct. Studies of surfaces of crowns and root tips of gold, porcelain, and acrylic resin which had been in contact with the gingiva for a long time showed cells similar to those composing epithelial attachment on extracted teeth. It was also shown that the relation between the epithelium and calculus, cement or root filling material may resemble an ordinary epithelial attachment.

Having demonstrated the epithelial attachment to be a histologic concept, but not a clinical entity, Waerhaug investigated the reactions when foreign substances were introduced between the free gingiva and the tooth. Bacterial, dental plaque and India ink were used to study tissue response. The foreign material was removed by an increased transudation of fluid and an emigration of leukocytes. Complete healing occurred.

This experiment was followed by another in which calculus was removed from human teeth two weeks or more prior to extraction. Epithelial cells were found

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adhering to the treated surface that correspond in all particulars to those composing the epithelial attachment of an untreated healthy tooth. From these studies, Waerhaug feels it is possible for the gingiva to defend itself against injury such as that caused by a temporary ingress of bacteria on a matrix band. Evidence was also presented that following effective removal of fixed irritants, such as calculus and the accompanying colonies of bacteria, satisfactory healing with readherence of epithelial cells and readaption of the gingiva occurs.

Fig. 1.

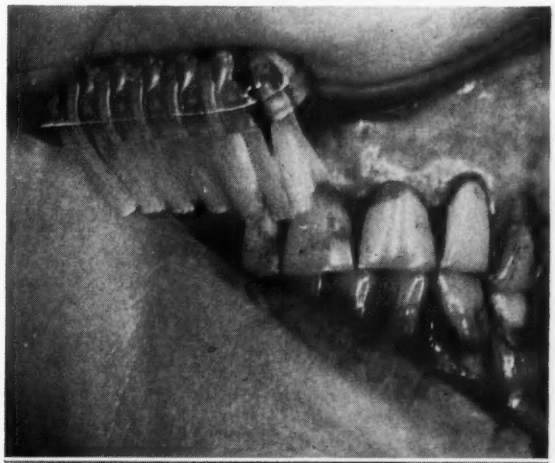

Fig. 2.

Fig. 1.—Cleansing teeth stained with basic fuchsin using soft bristle brush.
Fig. 2.—Cleansing gingival sulcus with soft bristle brush.

Zander[5] made a significant contribution to knowledge of the gingiva by inserting cellulose acetate strips, 0.1 mm. thick, between the free gingiva and enamel surface, then sectioning the tooth and soft tissues at later dates. His work supports and enlarges that of Waerhaug. The strip is measured when inserted into the sulcus and again in the microscopic section. The appearance of the junction between epithelium and acetate film is identical to that of an epithelium-enamel junction. A cuticle forms on enamel and also on the sides of the acetate strip. It is thought continuing studies with this technique should clarify some aspects of the clinical significance of the "epithelial attachment."

Studies of the connective tissue fibers of the free gingiva by Feneis,[6] Frolich,[7] Arnim,[8, 9] and Hagerman,[10] complete the picture of a dynamic, living, responsive tissue functioning as a protective cover for the underlying periodontium. A dense band of fibers encircling the tooth has been described in the free gingiva providing the supportive substance for maintaining physiologic adaptation of the tissue to the tooth. It is found in all healthy gingiva in humans, monkeys, and rats.

Fig. 3.

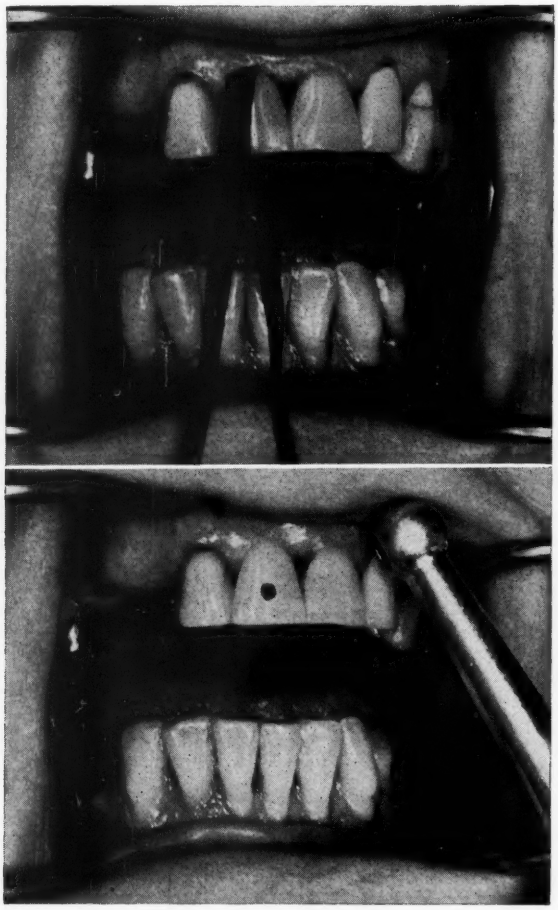

Fig. 4.

Fig. 3.—Dental tape floss (colored for contrast) used to clean underneath pontics.
Fig. 4.—Water spray for cleaning pockets and areas not reached by brush and floss.

The band is present during the stages of tooth eruption, in adult life, and in old age. The height of the gingiva does not materially influence the amount or nature of the fibers present. Those fibers nearest the crest of the gingival margin encircle the tooth. They anastomose freely with others attached to the crest of alveolar bone or cementum. Together they comprise a closely interwoven, compact, well-differentiated group. The presence of colonies of bacteria, firmly attached to the tooth surface, lead to the loss of these fibers with subsequent loose flabby gingiva and pocket formation. Correct treatment promotes healing with regeneration of the fibers and readaptation of the gingiva to the tooth surface.

The clinical significance of the investigations cited is that the careful dentist may work in the subgingival area between the enamel epithelium and the tooth surface without fear of serious permanent injury. Success of treatment in this region lies in skillful surgical technique which produces *little* trauma, removal of all irritants from the field of operation, and education of the patient concerning future personal oral hygiene.

Restorations may be placed beneath the free margin of the gingiva with safety when there is no cement line exposed, no overhanging filling material, and when the protective cervical contour is maintained. Some discrepancy may be allowable if the restoration provides no secure lodging place for bacterial masses, and the patient can be taught to keep the area between the gingiva and tooth free of injurious microorganisms.

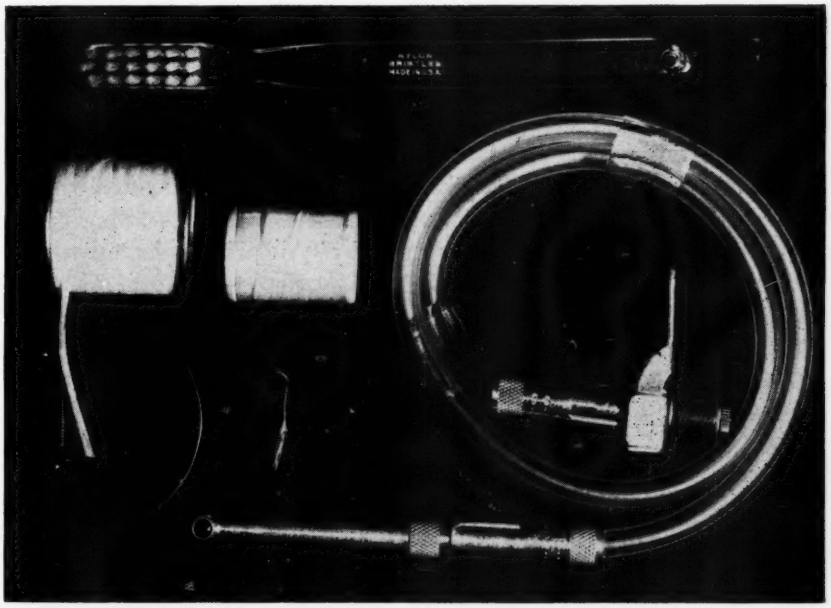

Fig. 5.—Soft bristle brush, tape floss, unwaxed nylon floss, curved needle, and water spray.

The advisability of extension of a restoration below the gingival margin is dependent on many other factors in addition to the reaction of the tissue to the operation or the resultant restorative material. Some of these factors are the patient's age, physical condition, susceptibility to dental caries, sex, vocation, the size of the carious lesion and surfaces affected, the condition of the dental pulp, position and health of the gingiva, type of restorative material, etc.

Fixed prostheses should be designed in such a manner that all surfaces in contact with oral mucosa can be cleaned thoroughly with brush, floss, and water spray. The patient should be taught effective personal oral hygiene.[11, 12] This is easily done where the bacterial masses on the tooth surfaces are stained with a suitable disclosing solution,[18] such as basic fuchsin. The germs are then shown to the patient with a *large hand mirror.* Their injurious potential to tooth and gingiva is emphasized. The psychologic effect of the brilliant red stain is excellent.

The patient is then given a soft bristle brush, and is told to direct the tips of the bristles at the stained bacteria, and to remove them from the tooth surfaces and from the gingival sulci (Figs. 1 and 2). The brush is followed by dental floss (Fig. 3). The floss is passed beneath fixed prostheses always. A curved needle may be used when necessary. Thorough rinsing with a patented water spray* completes the cleansing (Figs. 4 and 5). A hand spray can be made by use of a chip syringe and 12 inches of rubber tubing. The metal syringe tip is cut off near its base and the tubing is slipped over the cut ends. This allows the patient to squeeze the bulb forcefully and direct the spray accurately. The bacterial masses are always stained on recall for positive demonstration and accurate check on the effectiveness of the patient's cleansing techniques. The initial instruction must be repeated from time to time during recall appointments.

SUMMARY

Certain recent research on the gingiva that has a practical application to crown and bridge prosthesis is presented. The investigations discussed provide a concept which endows the free gingiva with physiologic attributes common to mucous membranes found elsewhere in the human body. These attributes are manifested by the ability of the gingiva to remove injurious agents from the subgingival areas, by its ability to repair injured and lost parts following operative trauma or infection, and by its ability to heal physiologic readaptation of the new gingival tissue to the tooth surfaces following complete removal of all injurious agents.

This biologic concept supports accepted clinical practices and provides the practitioner with basic scientific guides to successful treatment.

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# THE PROBLEM OF THE LOWER ANTERIOR BRIDGE

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ONE OF THE MOST annoying problems facing dentists who strive for perfection in both appearance and function is the replacement of the four lower anterior teeth. Fixed bridgework in these cases is most difficult from an esthetic standpoint, because plastic is still inadequate, and supported porcelain is quite friable.

Frequently, however, posterior teeth are missing in these cases, and often only the cuspid and occasional bicuspid remain. This presents a difficult situation. Those dentists who wish to relieve leverages on the abutment teeth can only partially succeed distal to the bicuspids, because they are faced with the problem of leverage incidental to direct stress on the artificial anterior teeth. Further, it is most difficult, at times, to place nice-appearing attachments in the cuspids or to place adequate rests to stabilize the anterior section.

Those dentists to whom time and expense are of no consequence solve the problem to their satisfaction by placing a fixed bridge in the anterior section and a stress-breaking removable appliance posteriorly. This is sound procedure, but it involves unnecessary time, questionable esthetics, additional expense to the patient, as well as a problem of hygiene.

The following technique may help to solve this problem. This idea was originally given to me in 1935 by Dr. Charles Hartley, who was applying this principle to an upper restoration, where splinting of the upper cuspids and rigidity of the six anteriors was indicated (Fig. 1). I have used this technique and many variations of it ever since.

## THE TECHNIQUE

1. Prepare the abutment teeth for three-quarter crowns and/or thimble crowns that can be jacketed.

2. Make an adequate master impression, and from it make a master cast from which these gold abutments can be removed and replaced at will.

3. Scrape the crest of the ridge sufficiently to assure tissue contact, and carefully adapt thereon a 12 or 14 gauge high-quality round wire. So adjust the wire that it can be soldered at both ends to the most linguogingival aspect of the gold abutments. Solder the wire in this position, and try the entire unit in the mouth to check for accuracy.

4. A routine gold casting may now be made by the usual procedure. This casting can be made to accommodate either gold or acrylic bases. It should encompass and extend anteriorly to the gold wire bar, with provision for the retention of the acrylic resin base.

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5. Teeth of any type can now be set upon this base, and most any type of esthetics developed. The abutment teeth and the bar carry all of the incisal stress (Fig. 2).

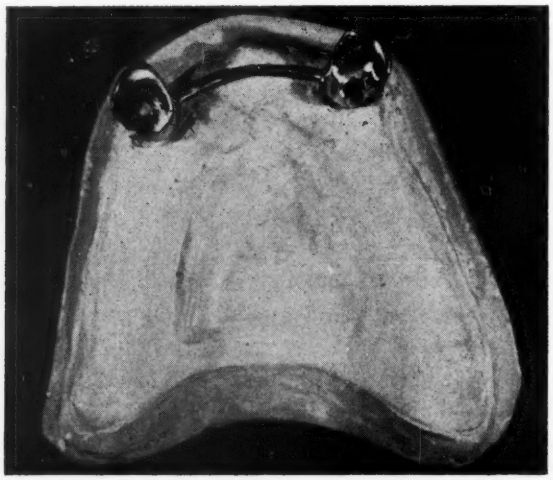


Fig. 1.—A cast showing the upper cuspids tied together with a 14 gauge round wire adapted to ridge.

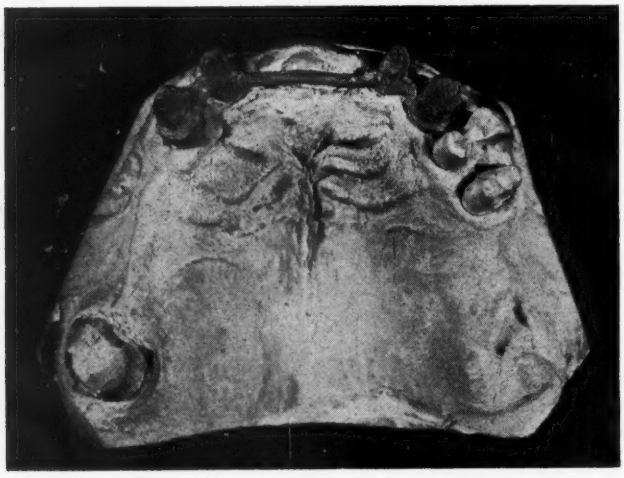


Fig. 2.—A cast showing gold thimble crowns which splint the cuspids to the lateral incisors, and the 14 gauge round wire on the tissue which ties all four together.

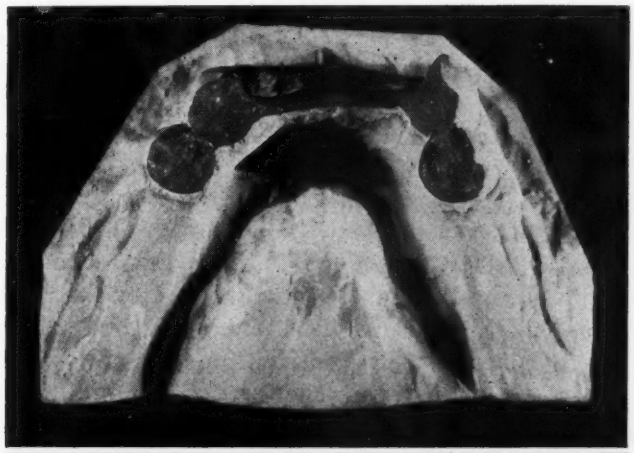
## ADVANTAGES OF THE TECHNIQUE

1. Good esthetics can be achieved easily.
2. The resultant removable anterior teeth have every advantage of a fixed bridge as regards rigidity in function.
3. The many advantages of splinting or bracing of abutment teeth are achieved (Fig. 3).

4. Ridge resorption ceases since it receives mild stimulation but has no direct stress placed upon it.

5. This same principle can be applied in either the upper or lower arch. It can be used for splinting or spanning other short spaces in the posterior part of the mouth, and for stabilizing individual teeth (Fig. 4).

Fig. 3.



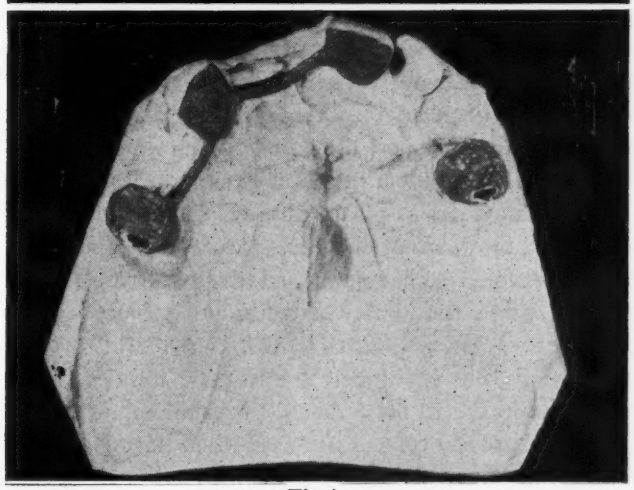


Fig 4.

Fig. 3.—A cast showing a bar to carry the four anterior teeth soldered to the cuspids and bicuspids which are splinted together.

Fig. 4.—A cast showing how the cuspid was supported and tied to the central incisor and the second bicuspid. This makes the teeth supported by these bars very solid and minimizes the number of attachments necessary for the retention of the partial denture.

6. This method is less costly to the patient because it is simple to use, and the breakage factor is negligible.

7. It is obvious that it is very easy to keep these splint bars, as well as the tissues around them, clean.

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# A NEW METHOD OF DETERMINING THE FUNCTIONAL FORCES APPLIED TO PROSTHETIC APPLIANCES AND THEIR SUPPORTING TISSUES

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A KNOWLEDGE OF THE functional forces that occur in the mouth has important application to every branch of dentistry. Of particular importance in prosthodontics is an understanding of (1) those forces applied to prosthetic appliances under function and (2) those forces applied by the restoration to the ridge arch and supporting tissue. Complete physical analyses of these functional forces and the determination of their numerical properties can provide new basic criteria for evaluation of (1) the efficiency of various types of restoration design and (2) the standards of minimum mechanical strength necessary for dental materials and prosthetic appliances.

In an earlier article,[1] I described a method of accurately determining the direction of the force acting on denture teeth during mastication. The method was there first applied to the problem of full denture stability. The knowledge of the precise direction of this force and the equations in which it is embodied is the first step which now makes possible a program of general force analyses for specific dental problems. A detailed discussion of physical force analysis will be described which will give for each tooth situation precise knowledge and an accurate understanding of all the functional forces acting on the natural or artificial teeth, the supporting edentulous ridge, the abutment teeth, and soldered joints of fixed and removable partial dentures, etc. No attempt will be made in this article to present actual numerical solutions, but I will merely introduce and describe the significance of the new analytical approach to these dental problems.

Physical approaches closely related to this method have been used to advantage in other nondental fields of prosthetics—such as in studies of artificial limbs, etc.; and this type of study should prove of great practical value in dental science.

## FUNCTIONAL FORCES

Of all the functional forces applied in the mouth, the greatest occur during mastication. Consequently, the discussion will be confined to this process, and in

This article is based partly on a lecture entitled "Forces Applied to Dental Materials During Mastication," presented to the International Association for Dental Research, March, 1953. It is a continuation of research initiated by the author when he was a Captain in the U. S. Army and a guest worker at the National Bureau of Standards Dental Research Section.

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this article all references to *functional forces* shall be understood to mean those forces that exist solely during mastication.

I will explain and apply to the process of mastication the methods of physics which are found in the analytical mechanics chapters of any elementary textbook on physics or engineering[2-4] (such as those used in the college physics course required of all predental students). By this means one can distinguish between various forces in the mouth, each of which is exerted *on* one body *by* another body (the word force being used here exclusively in the technical sense of any physics textbook). For example, forces are exerted *by* the various muscles, *by* the food mass, *by* the materials of the dental appliance, *by* the oral mucosa; and forces are exerted *on* the food, *on* the dental materials, *on* the oral mucosa, etc. Since many of these forces are induced by other forces, it is never necessary for any particular problem to consider all the forces acting at one time in the mouth, but only those forces acting *on* the particular body in question. This distinction between those forces that are exerted *on* the particular body under study as distinct from those forces exerted *by* that body on any other bodies is a vital one and must always be kept in mind.[5]

The force analysis will examine first those functional forces that act on the dental restoration, for when they are completely known, immediate application can be made to the forces acting on the oral mucosa and ridge arch.

The external effect of a direct force applied to a solid body that is at rest is to develop resisting or reactive forces, exerted on the given body by other contacting bodies. The internal effect of such a direct force is to produce stress and deformation in the body on which the force acts.[5] For functional forces acting on a prosthetic appliance, the former effect has practical application to the appliance design, and the latter effect has practical application to the strength of the materials of the appliance itself.

## FORCES EXERTED ON DENTAL RESTORATIONS

*Types of Functional Forces: Direct and Reactive.*—The functional forces on a solid body (the prosthetic appliance) may be classified into two types: (1) the direct functional forces and (2) the reactive functional forces. The difference between these two force types and the concept of balanced forces exerted on an object is illustrated in Fig. 1.

When a functional force in the form of a truck is applied to a road bridge, a direct force equal to the weight of the truck is exerted by its tires on the bridge. Since the bodies in question remain at rest (the bridge does not collapse under the weight of the truck), there is a balancing reactive force exerted on the bridge which is evidently the force of the bridge abutments pushing it up. This reactive force on the bridge exerted by the abutments is actually induced by the truck weight on the bridge.

*Type of Reactive Force.*—The type of reactive force induced depends on the nature of the tissues supporting the dental restoration (e.g., hard tooth structure, oral mucosa, etc.). By type of reactive force is meant the different places of application of the force and the distribution of magnitudes of the forces applied to

the restoration. That the type of reactive force depends on the particular characteristics of the supporting structure should be evident from the analogy in Fig. 2.

The unhappy gentleman at the top is sleeping on a wooden bed. Comparing the forces exerted on his anatomy with those of his more comfortable friend on the foam rubber mattress below, it is quite obvious that the reactive forces are exerted in different places with different magnitudes and depend on the supporting structures.

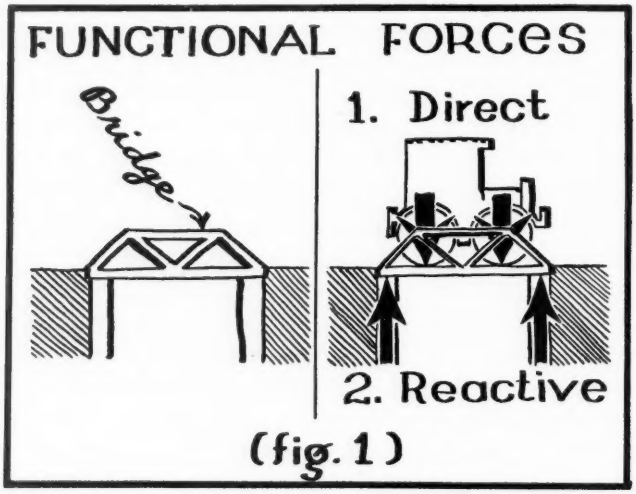


Fig. 1.—Reactive forces are induced by direct forces. Here the direct force 1 of the weight of the truck induces a reactive force 2 which is exerted on the bridge by the abutments.

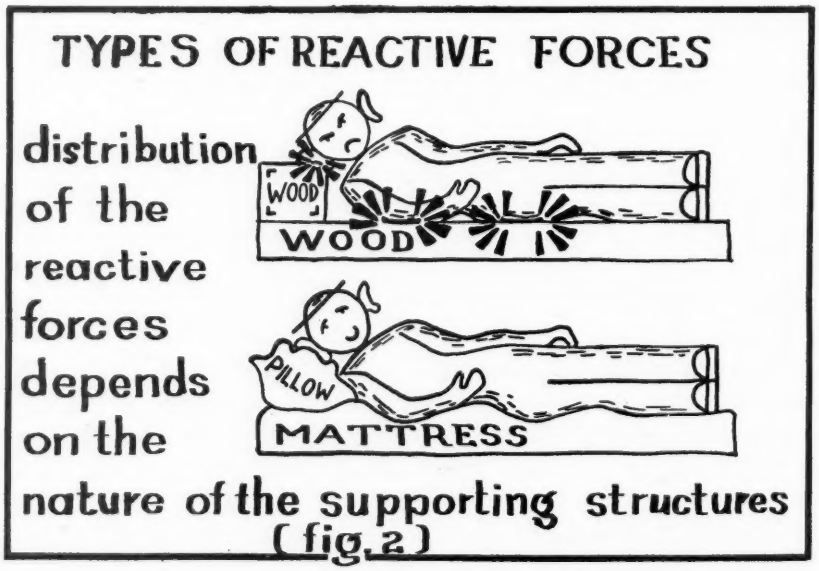


Fig. 2.—The direct force, the weight of the man, is the same in both pictures. The reactive forces differ in places of application and the distribution of magnitudes.

*Method of Calculating Reactive Forces When the Direct Functional Forces Are Known.*—It is clear that the reactive forces are a result of and are induced by the direct functional forces. Once the direct forces are known, the reactive forces can be calculated. The principles and methods used in calculating the direct functional force together with the reactive force induced by the direct force can be seen by illustration (Fig. 3).

Here a man is pulling on a handle that is firmly screwed to a wall; and it is desired to know all the forces on the handle. The direct functional force on the handle is the force exerted by the man; and this force must be measured. This can be accomplished easily by putting a spring scale between the man and the handle and by simply reading the length of spring extension of the scale. (It is to be noted for future analogy that here, in order to find the direct functional force, one measures simply a significant length, i.e., the extension of the spring.)

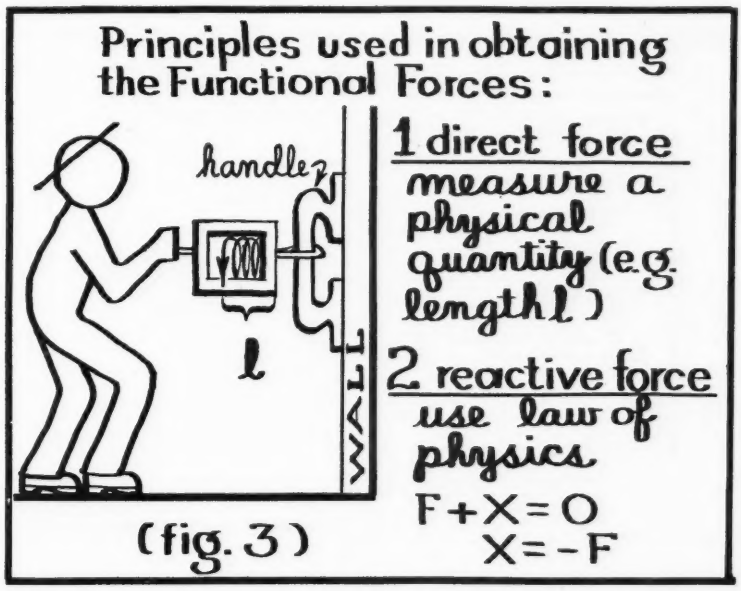


Fig. 3.—This simple analogy shows that when the direct functional forces are measured, the reactive forces induced can be calculated by physical laws. Here the man exerts the direct force, inducing a reactive force exerted by the wall.

The reactive force is obviously that exerted on the handle by the wall; and, since the handle is not moving, the sum of the forces on the handle must be equal to zero. (One recalls from elementary physics that $F = mA$, where $F$ = force, $m$ = mass and $A$ = acceleration; and since the acceleration of the handle is zero, the sum of the forces on the handle must also be zero.) Suppose the man is pulling with a force of F pounds. Then if X represents the unknown force exerted on the handle by the wall, one must have $F + X = 0$, and therefore $X = -F$. Thus this simple calculation shows that the wall is pulling on the handle, with exactly the same force as the man, but in the opposite direction.

In this analogy to the two functional forces on dental appliances, one sees that the direct force was obtained by physical measurement, and the reactive force calculated from basic physical laws. Exactly the same principles will be applied to the dental analysis.

## DIRECT FORCE EXERTED BY THE FOOD BOLUS ON NATURAL OR ARTIFICIAL TEETH DURING MASTICATION

*Dispelling a Recurrent Myth.*—The direct functional force in the mouth is the force exerted by the food mass on the teeth; and both physical measurements and a correlating chart are necessary to obtain the direction of this functional force on the dental restoration. Before explaining the actual method by which this is done, however, it is important to first discuss some objections which are often raised to show why it cannot be done.

The myth of unsolvability which arose about this problem is based on the erroneous conclusion that since each of the many muscles involved in mastication pulls in a different and not precisely known direction, and since the source of the forces of mastication arises through this complex muscular action, therefore it is impossible to ever actually determine the exact direction of the resultant force on the teeth. This erroneous conclusion drawn from true premises is at first glance deceptively convincing. It can, however, be easily dispelled as a mere myth.

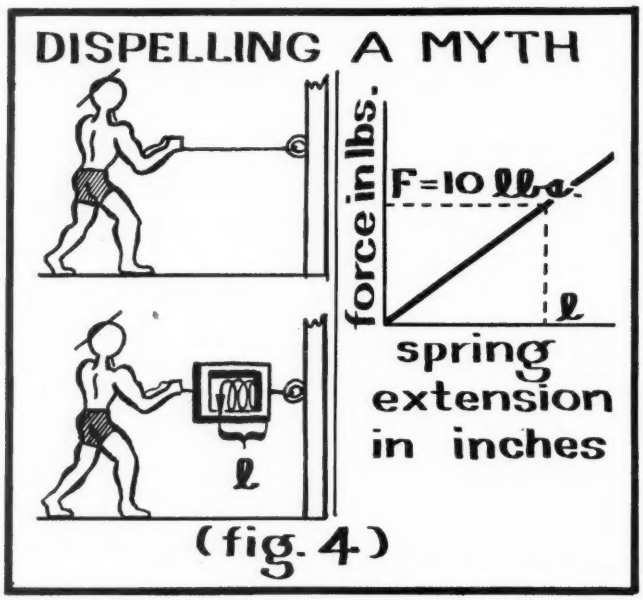


Fig. 4.—The man pulls on the wall, using many of his muscles. The net result is a single force which can be measured with a spring scale. The length the spring is extended is related to the force applied in pounds as shown in the graph.

Consider Fig. 4, for example, and the man pulling on the wall. He is pulling with his fingers and with his hands, with his arm muscles, his back muscles, and his leg muscles. At first glance, it certainly seems a difficult and overwhelming problem to determine the resultant of all these separate muscular actions. But the problem is easily solved by merely placing a spring scale between the man and the wall and measuring the extension of the spring. By means of a graph or chart associated with this particular spring scale, one can find the actual correlation of the force in pounds in terms of the length in inches of the spring extension. In this way, one can completely by-pass the actions of the individual

muscles and find their resultant force by performing a simple measurement. (Note that it is not necessary to read a chart or graph for the simple case of a scale which usually has a built-in calculated calibration which reads the force in pounds directly. However, the actual graph gives a more precise analogy to the more complex but just as straightforward dental situation.)

Thus, by taking certain measurements and by using a graph, one can by-pass the individual actions of the muscles of mastication and determine merely their net effect, which is the exact direction of the functional force the bolus of food exerts on the teeth in the closing motion of chew.

*Determining the Direction of Force by Measurements and Graph.*—In my earlier article,[1] it was shown that the exact direction of the functional food force depends on three factors: (1) the angular slope of the mean tooth surface and the steepness of the cuspal incline, (2) the angle of chew of the patient, and (3) inherent characteristics of food which are embodied in an experimental constant and thus fixed.

The actual formula relating these quantities is:

$$\tan F = \frac{K \tan S + \tan (M\text{-}S)}{K - \tan (M\text{-}S) \tan S}$$

where M is the angle of chew, S is the tooth surface slope, F is direction of force (M, F, and S being measured with respect to a fixed "horizontal" plane), and K depends upon a constant and e, the cuspal incline (Fig. 5).

Thus, to know the actual direction of the direct food force on a patient's teeth, three sets of measurements must be taken for that individual. The first two of these sets of measurements are concerned with the shape and positioning of the artificial or natural tooth surfaces; the last is a physiologic measurement associated with the patient's chewing habits.

In Fig. 5 is illustrated (1) the measurement of S, the tooth surface slope, which is the angle between the cuspal peak plane and the horizontal reference plane; and (2) the cuspal incline e which is the angle between the cusp slope and the cuspal peak plane. Note that flat teeth have a cuspal incline of e=O.

The third measurement is the angle of chew M (Fig. 6). Chewing occurs, with few exceptions, on one side of the mouth at a time. The motion of the lower jaw with respect to the upper may be roughly described as opening with a downward path followed by a lateral movement toward the side on which the chewing is taking place and a final closing motion upward into centric occlusion. These mechanics of jaw motion have been demonstrated by many investigators[6-9] using simple extraoral devices for making chewing tracings. The angle of chew M is the angle measured between the reference "horizontal" and the final closing motion, which is the time when the maximum force is exerted.

When these three measurements have been taken, the exact direction of the force of the food on the tooth (as obtained from the above equations) can be read on the graph (Fig. 7).

The numbers along the vertical axes represent values of S, the various tooth surface slopes; while F, the directions of the force, are along the horizontal axes. Note that there are several such coordinate systems (or sets of axes); in fact, one exists for each angle of chew M. Axes have been drawn for each 10° change

in M. (i.e., M=90°, 80°, 70°, 60°, and 50° as shown). Thus, for a given tooth surface slope and angle of chew as measured on the patient, the resulting direction of force is found as follows:

Choose the axis set corresponding to M, the angle of chew. Then on this proper axis set, locate the desired tooth surface and draw a horizontal line until it

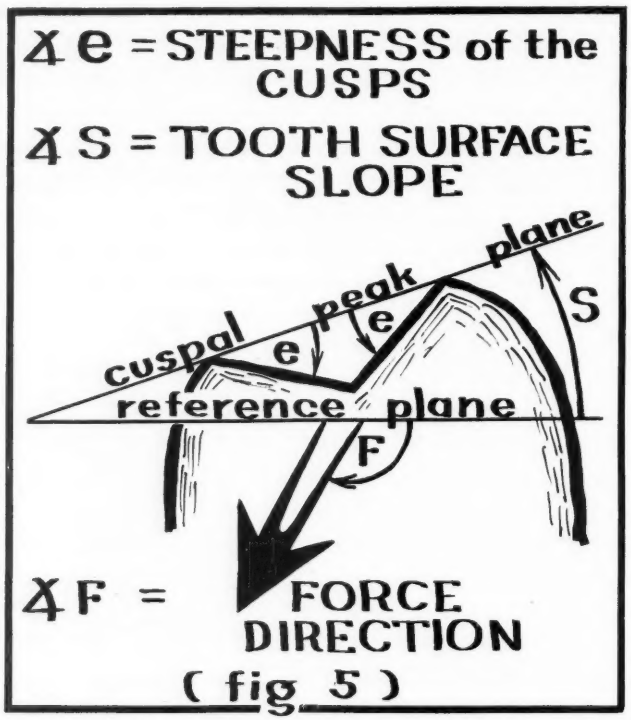


Fig. 5.—Diagram of significant measurements. S = tooth surface slope, angle between the cuspal peak plane and the "horizontal" reference plane; e = cuspal incline, angle between the cusp slope and the cuspal peak plane; F = direction of force, angle between force vector and "horizontal" reference plane.

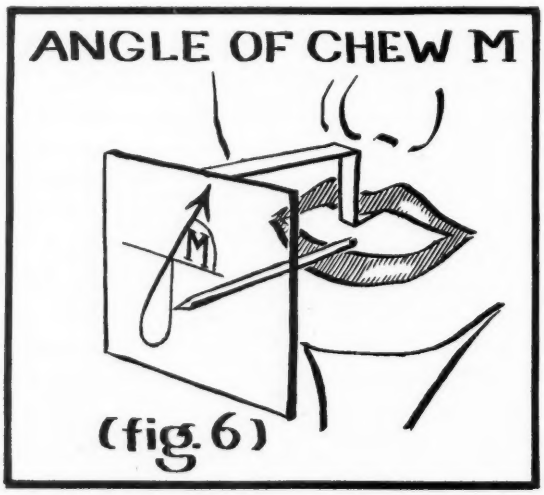


Fig. 6.—M is the angle measured between the horizontal reference plane and the final closing jaw motion, as traced on the card during chewing.

meets the curve. When a vertical line is dropped from this point until it meets the proper axis, one can read here the value of the direction of force. For instance, suppose for a given case M=80° and S=20°. The M=80° axis is chosen and S=20° located. The dotted horizontal line is drawn across to meet the curve. When a vertical line is dropped from this point to the correct axis set, one can easily read the force direction as 75°.

The curve drawn on this graph is labeled "curve for flat teeth, cuspal slope =0°." There are different curves for e, different cuspal slopes. For simplicity in this illustration, these other curves have not been drawn.

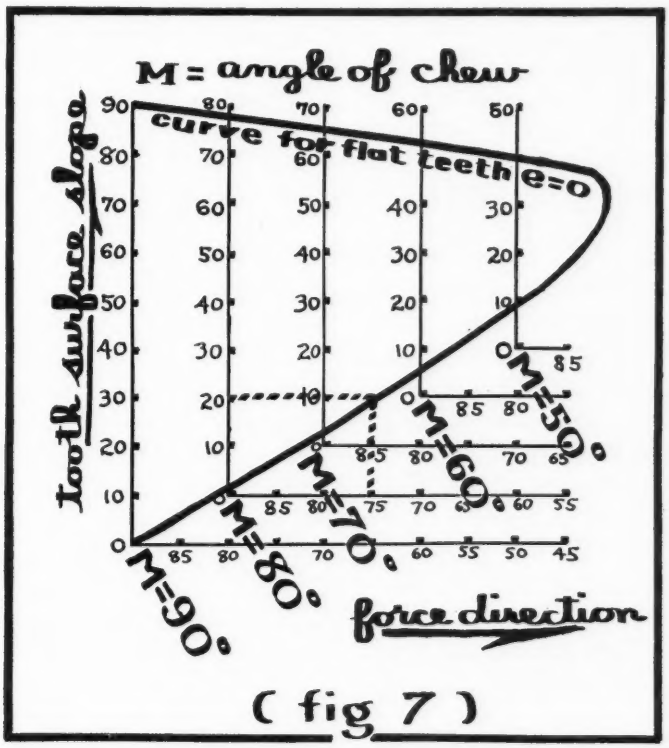


Fig. 7.—Graph showing how the value of the force direction F depends on the angle of chew M and tooth surface slope S. One chooses the proper set of axes corresponding to an angle of chew of 90°, 80°, 70°, 60°, or 50° and locates the proper tooth surface slope on the vertical axis. A horizontal line is drawn until it meets the curve, and then a line is dropped to the corresponding horizontal axis where the value of the force direction is read. Thus, an angle of chew of 80° and tooth surface slope of 20° will result in a force direction of 75° as shown by the dotted lines.

The entire discussion so far has considered only the frontal cross section. The cuspal slope, tooth surface slope, and angle of chew have been measured in the frontal plane while the direction given by this graph is that of the frontal component of the force. For a complete three-dimensional determination of the force direction, one also must have the direction of the force in the sagittal plane. This can be accomplished by determining the cuspal slope, tooth surface slope, and angle of chew in the sagittal plane; then one uses this new sagittal data with the same graph, to find the sagittal force direction.

*Magnitude of the Force.*—By the use of a gnathodynamometer, the magnitude of the vertical component of the force of mastication can be measured. These three numbers (the angle of the frontal direction, the angle of the sagittal direction, and the magnitude of the vertical component) completely determine all properties of the magnitude and the direction of the force exerted on the teeth by the food during mastication.

## THE DISTRIBUTION OF REACTIVE FORCES IN THE MOUTH

Once the nature of the direct forces on a dental restoration have been determined by measurements on the patient and by the method just described, the reactive forces thus induced can be calculated from the laws of physics. The result is a description of all of the functional forces acting on the restoration.

Further, since every force is associated with an equal and opposite force at its point of application, when one knows the force applied to any point of the restoration by the oral mucosa and ridge arch, it follows that the force applied at that point to the ridge and oral mucosa by the restoration is equal in magnitude and opposite in direction.

For examples of the results obtainable by such calculations, we will touch upon the most elementary phases of two problems. The examples are meant not to present particular results, but rather to show the general power of the method and the great variety of practical dental applications of such studies.

*Force Distribution on a Lower Complete Denture.*—When one knows the direct functional force of the food on the artificial tooth surfaces of the lower complete denture, the problem is to determine the distribution of the reactive force exerted by the oral mucosa on the tissue-borne surface of the denture. The complete solution to this general problem is, of course, extremely complex; and we shall consider here merely the simple special case where the oral mucosa has the same physical characteristics on both ridges, and the bearing area of the lower denture is about the same on right and left sides. We will find what per cent of the vertical component of the direct functional force gives rise to the vertical component of the reactive force of each ridge. Also since the force with which the denture pushes down on each ridge is equal and opposite to that reactive force with which the ridge pushes up on the denture, we can tell what per cent of the vertical component of the direct functional force gives rise to the vertical component of the force on the right ridge, and what per cent gives rise to the vertical component on the left ridge. (See Appendix 1 for the actual computation.)

If the direct force falls outside of the ridge arch, then the reactive force on the chewing ridge comprises the entire reactive force, there being no functional vertical force exerted by (or naturally on) the left ridge in this case. This result is rather obvious when one considers the analogy of the boy sitting on the board (Fig. 8). When the force is directed outward, the board will lift up on the other side, just as the denture tends to do. However, when the direct functional force falls inside the arch, then the reactive forces' vertical component is distributed over both the right and left side bearing area. The exact distribution of the reactive force between the right and left side bearing areas involves the average distance between the posterior ridge crests and the partitioning of this distance by the force vector as illustrated. The farther toward the left (nonchewing) side

the force is directed, the more the vertical component of the reactive force falls on the left ridge. In practice this distance must be kept small. Also, since the direction of the direct functional force depends on the chewing habits of the patient as well as the dentist's choice of occlusal surface slope, the direct force cannot be directed in a completely arbitrary way.

These results about the reactive force applied to a completely symmetric lower complete denture and the ridges are evidently of a rather trivial nature. However, on more advanced analysis, the exact distribution of the pressure on each ridge can be ascertained.

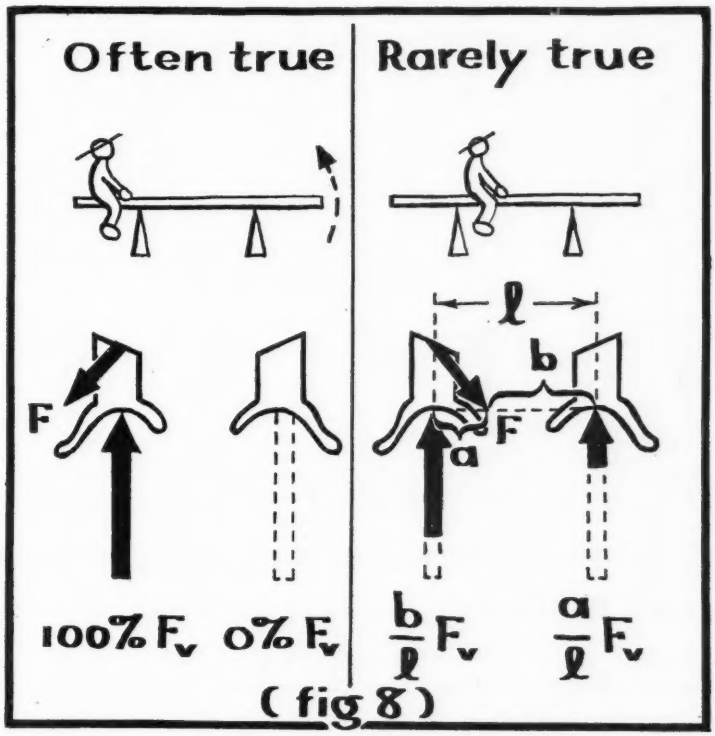


Fig. 8.—Distribution of forces on a lower complete denture. The patient is chewing on the right side. If the direct force F falls outside the ridge arch, 100 per cent of the reactive force is borne by the chewing ridge with no vertical force on the left ridge. If the direct functional force F falls inside the ridge arch, the vertical component $F_v$ is distributed over right and left ridges, the exact numerical ratio depending on the average distance between the ridges and the partitioning of this distance by the force vector.

*Forces Applied to a Fixed Bridge and Its Abutment Teeth.*—The second example is that of a one pontic posterior fixed bridge where the abutment teeth are in good health, and the force of mastication is distributed equally over the abutment and pontic tooth surfaces. Considering a simple situation where the direction of the force applied by the food on the teeth is assumed to be vertical, we wish to know how this load or force on the pontic is distributed on the abutment teeth (the distribution of forces on the abutment teeth is due to the reactive forces exerted on the abutment teeth by the bony sockets).

Considering the bridge and abutment teeth as a rigid body resting on a somewhat springy layer, the periodontal membrane, the calculation in Appendix 3 gives the distribution of the reactive forces on the abutments in various designs.

Since the direct food force is considered equally distributed, the results will be given in terms of the increase of the force on the abutment tooth due to its use in a fixed bridge or, in other words, in the per cent of the load on the pontic which is carried by each of the abutment teeth.

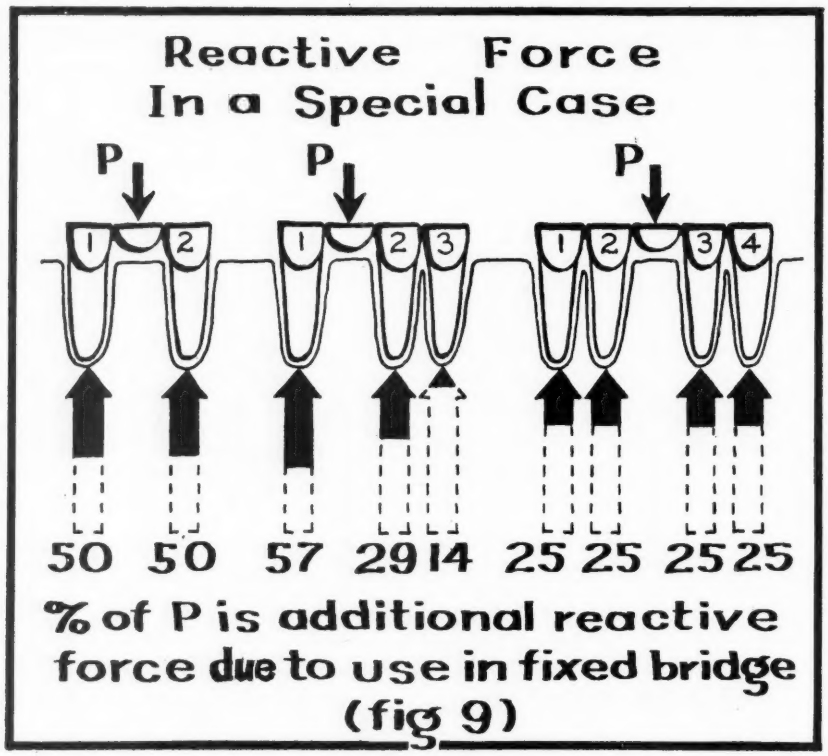


Fig. 9.—Distribution of forces on the abutment teeth of fixed bridges. The direct force, P, on the pontic induces reactive forces that are borne by each of the abutments. The increased load on each abutment is shown by the percentages in the figure.

For the two-abutment fixed bridge (Fig. 9), the load on each abutment tooth has been increased by 50 per cent of its normal load. For a three-abutment fixed bridge, the load increase on the first abutment is 57 per cent, that is an even greater increase on this tooth than in the two-abutment bridge. The increased load on the second abutment is 29 per cent, which is substantially less than in the two-abutment bridge. The load increase on the additional third abutment is only 14 per cent, or not a very considerable amount.

For a four-abutment bridge, the load increase on each of the four abutments is 25 per cent, which is quite an improvement over the two-abutment bridge.

*Practical Application of the Results.*—The dentist strives to design a prosthetic appliance which will distribute the reactive forces in a manner most conducive to

the health of the supporting tissues. Thus, results of the type obtained in this section have a direct practical application to the design of prosthetic appliances. In the first example, it is seen that for a lower complete denture, in order to distribute the vertical component of the direct functional force onto both ridges, the slope of the tooth surface must be set so the direct force falls inside the ridge arch. The second example shows that, for the fixed bridge, the addition of a third abutment increases the load on the lone abutment which may not be desirable in certain clinical situations.

### STRESSES IN DENTAL RESTORATIONS INDUCED BY FUNCTION

Once one knows all the functional forces which are being applied to a dental restoration, one can calculate directly the tension, shearing forces, twisting couple, and bending moments that are induced at any point interior to the dental material by function.

Thus, for each of the two dental situations above, we can calculate the shearing force and the bending moment at critical points in the restorations.

*Some Stresses on a Lower Complete Denture.*—At a point opposite the labial frenum on the lower complete denture, it is shown in Appendix 2 that the total force tending to shear the denture is: $S = hF_v \, l \tan F$, where $F_v$ is the vertical component of the force, F, the angle between the force and the horizontal, h, the height of the tooth, and $l$, the distance between the ridges. Furthermore, the total moment of bending at the same point is: $M = hF_v/2 \tan F$. Some idea of the numerical magnitudes of these quantities (Fig. 10) can be had on substitution of the following reasonably average values: $F_v$=30 lb., F=80°, h=¼ in., $l$=2 in., whence (in absolute value), S=⅔ lb. and M=⅔ lb. in.

*Some Stresses on a One Pontic Bridge.*—A similar analysis of the fixed bridge example, as done in Appendix 4, gives information as to the shear and bending moment at the soldered joints of the various bridge designs. The exact results given there can be approximated numerically (Fig. 10) if one considers the vertical force P on each tooth to be about 30 lb. and a, the width of the tooth, to be ⅜ in. If $S_{1,p}$ represents the shear at the soldered joint between the first abutment and the pontic and $M_{1,p}$ the bending moment at that point, then for the two-abutment bridge:

$S_{1,p}$= 15 lb. $M_{1,p}$= 2.8 lb. in.
$S_{p,2}$= 15 lb. $M_{p,2}$= 2.8 lb. in.

for the three-abutment bridge:

$S_{1,p}$= 17 lb. $M_{1,p}$= 3.2 lb. in.
$S_{p,2}$= 13 lb. $M_{p,2}$= 4.0 lb. in.
$S_{2,3}$= 4.3 lb. $M_{2,3}$= .8 lb. in.

and for the four-abutment bridge.

$S_{1,2}$= 7.5 lb. $M_{1,2}$= 1.4 lb. in.
$S_{2,p}$= 15 lb. $M_{2,p}$= 5.6 lb. in.
$S_{p,3}$= 15 lb. $M_{p,3}$= 5.6 lb. in.
$S_{3,4}$= 7.5 lb. $M_{3,4}$= 1.4 lb. in.

*Intuitive Picture of Force Magnitudes.*—For an intuitive concept of the order of magnitude of the shearing forces and bending moments above, consider an experiment (Fig. 10), where a tongue depressor is placed across a 1 in. gap between two tables. If bags of sugar totaling 20 lb. are tied exactly ¾ in. from one table edge, the maximum shearing force on the tongue depressor is 15 lb., and the bending moment is 3¾ lb. in.

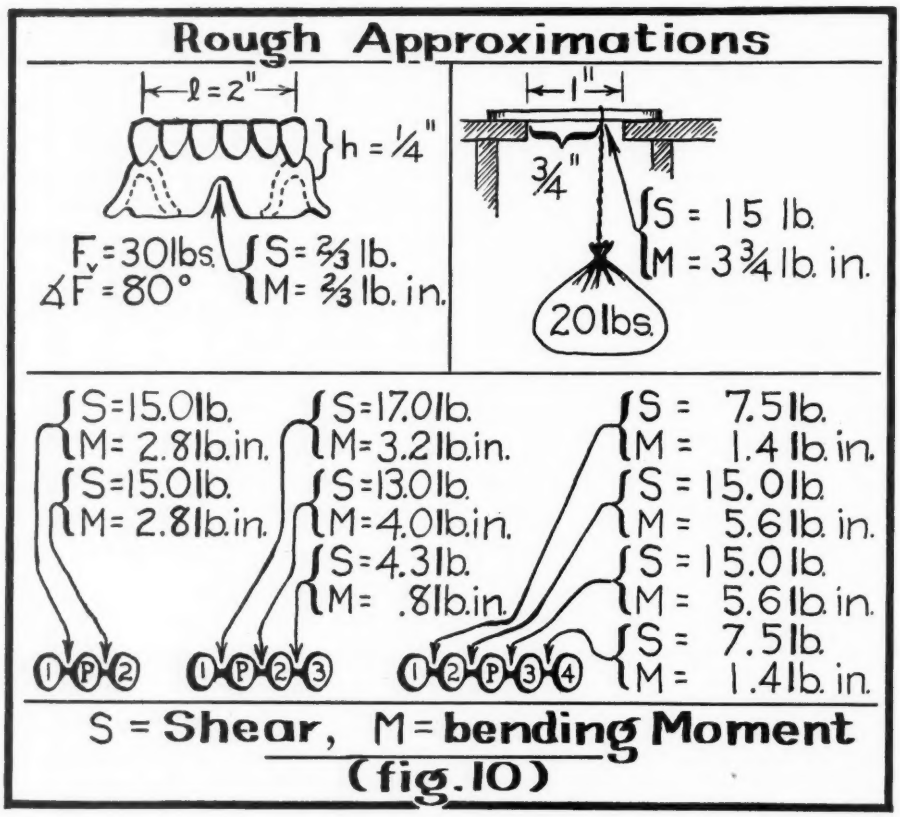


Fig. 10.—Approximations of internal stresses induced in prosthetic appliances during mastication. (Above, left) Lower complete denture: If the average distance between the ridges is 2 inches, the height of the occlusal tooth surface above the ridge is approximately ¼ inch, and the direct force is as shown, the internal stresses tending to shear and bend the denture at a point opposite the labial frenum are given. (Below) Fixed bridges: The forces tending to shear and bend the bridge at each soldered joint are shown as would occur for a direct force of approximately 30 pounds on the pontic and an average mesiodistal tooth width of ⅜ inch. (Above, right) An intuitive idea of the magnitude of these internal stresses can be seen with the following experiment. When a tongue depressor is placed across a 1 inch gap between two tables, and 20 pounds of sugar suspended from it ¾ inch from one table edge, the shear and bending moment in the tongue depressor have the maximum magnitudes shown.

*Practical Application of the Results.*—These examples have been chosen from simplified situations, since in general, the analyses are necessarily far more complex and technical than those presented here. These are meant to be merely an indication of the types of results these methods are capable of producing. From the

first example, it is clear that specifications for strength of denture materials can be evaluated with respect to this type of real functional data; and, from the second example, one sees that such data are of importance in estimating the relation between the strength of soldered joints and fixed bridge design.

## SUMMARY AND CONCLUSIONS

Any successful prosthetic appliance not only must withstand those forces arising during mastication but must distribute these forces in a manner compatible with the continuous health of its supporting tissues. Thus, of vital importance to prosthodontists is a knowledge of all the functional forces that occur in the mouth. These functional forces are of two main types: (1) the direct force applied to the occlusal tooth surface directly by the contacting bolus of food during chewing and (2) the reactive force induced on the mucous membrane, teeth, bone, etc., supporting the prosthetic restoration.

A new method of physical force analyses has been described which makes possible a thorough understanding and precise calculation and description of these forces. The determination of the direct force is based on certain physical measurements of the tooth itself plus a physiologic measurement of the patient's habitual angle of chew. These various factors affecting the direct force of the food acting on the occlusal surface have been discussed in detail; and it was indicated how, once the direct force is known, the reactive forces can be calculated by means of the principles of physics.

The second part of this article extended this theory to a discussion of those stresses and strains which are induced internally at various strategic points in the prosthetic restorations during the process of mastication. As an example of this method, the analysis was done in detail for certain relatively simple complete dentures and fixed bridges, where the results gave the distribution of forces on the ridges and abutment teeth, respectively, and also the shearing force and bending moment which occur at critical points of the denture and bridge, respectively.

This type of analysis, when applied to any specific type of mouth situation and restoration design, presents a complete description of (1) those forces applied to the restoration by the bolus of food and by the supporting structures, (2) those functional forces applied to the supporting tissues (including details of force distributions on ridges and on supporting abutments), (3) those forces of stress and deformation of strain induced in the material of the dental restoration itself, under function.

Projected future articles will present means whereby, for a reasonably average range of tooth dimensions and physiologic measurements and for common cases and types of restoration design, the dentist can determine the various forces described above, by mere observation of graphs and charts.

This type of program is designed to present a new realm of information available to the dentist which will enable a more critical evaluation of the effectiveness of various possible designs of restorations for given situations as well as standards for evaluation of the physical properties of present-day restorative dental material themselves.

## APPENDIX

1. *Reactive Forces on a Lower Complete Denture.*—Fig. 11 represents a schematic diagram of a frontal cross section of the lower full denture resting on the ridges. Here the functional food force on the chewing side is represented by the vector F, with horizontal and vertical components $F^h$ and $F^v$ respectively; $<F$ is the angle between the vector F and the horizontal; h is the height of the tooth, and $l$ is the distance between the ridges which is partitioned by the force vector into lengths a and b as shown.

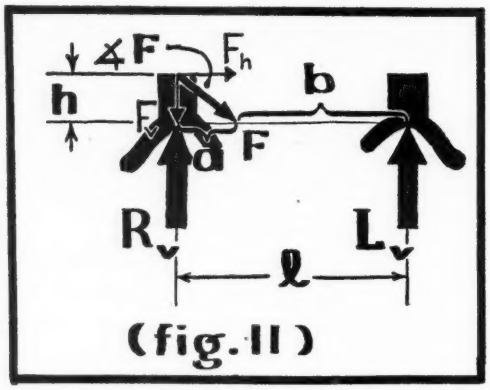


Fig. 11.—Force diagram for lower complete denture calculations.

The reactive vertical force of the right and left ridges are labeled, respectively, $R_v$ and $L_v$ and are the magnitudes we wish to determine.

Since the sum of the forces on the static denture is zero, we have in the vertical direction:

(1) $R_v + L_v - F_v = 0$,

and since the sum of the moments about any line is zero, the particular consideration of the line of the right ridge crest, gives:

(2) $L_v l - F_h h = 0$.

These two equations plus the obvious geometric relations: $\tan F = F_v/_h = h/a$, and $b+a = l$ yield the solutions:

$L_v = aF_v/l$ and $R_v = bF_v/l$ as presented in the text.

2. *Shearing Force and Bending Moment on a Lower Complete Denture.*—To calculate the total vertical shear S at a point or the bending moment M about any line in the denture, one considers the denture as if it were two separate parts and calculates the respective total vertical force and torque exerted on one part by the other. From these considerations and Appendix 1, it follows that for a point opposite the labial frenum: $-S+L_v = 0$, whence the total shear: $S = L_v = hF_v/l \tan F$; and $-M+lL_v/2 = 0$, whence the total bending moment $M = lL_v/2 = hF_v/2 \tan F$. (Note that in these calculations the force exerted on the denture by the anterior arch has been neglected.)

3. *Distribution of Reactive Forces on Fixed Bridge Abutments.*—The analyses of the distribution of the reactive forces on the various abutments for the three different bridge designs are naturally similar, details of the computations being presented here for only the asymmetric three-abutment bridge, which is the most complex. The rigid bridge cemented to the abutment teeth is considered here to move as a solid unit, both ends resting on the soft periodontal membrane, which under functional force depresses slightly. The reactive force exerted by the periodontal membrane on the abutment tooth is, to a first order approximation, proportional to the vertical displacement of the abutment. (For if t is the displacement of an abutment into the periodontal membrane, there is some f(t), such that $F = f(t)$ is a precisely accurate description of the resulting force F. A Taylor expansion gives $F = K_0+K_1t+K_2t^2+ \ldots$, where for a first order approximation $F = K_1t$, since $K_0$ is evidently zero from the physical considerations.) (The intuitive analogy to a pontoon bridge is evident.)

In the schematic diagram Fig. 12, all forces are assumed as acting at the center of the tooth surfaces, P is the vertical force on the pontic, and a, the width of the tooth. The new displaced coordinates of the abutment bases are $(0,t_1)$, $(2a,t_2)$, $(3a,t_3)$, whence from the above the reactive forces $F_1 = -Kt_1$, $F_2 = -Kt_2$, $F_3 = -Kt_3$, are the quantities we wish to determine.

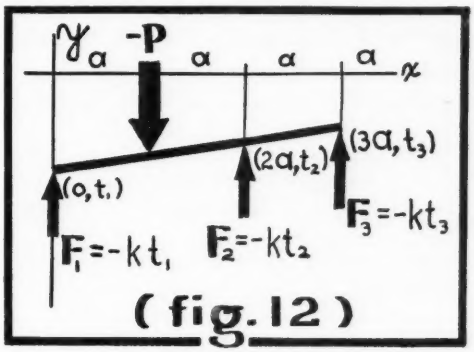


Fig. 12.—Force diagram for the three-abutment fixed bridge calculations.

The sum of the forces in the y direction is zero, hence:

(1) $-P - Kt_1 - Kt_2 - Kt_3 = O$

and, equating the sum of the torques through the point $(2a, t_2)$ to zero yields:

(2) $-Kt_3\ (3a-2a) - P(a-2a) - Kt_1(O-2a) = O.$

However, since the bridge is considered as rigid, it is geometrically evident that $t_2 = t_1/3 + 2t_3/3$ and on substituting and solving (1) and (2) one has:

$t_1 = -4P/7K$, $t_2 = -2P/7K$, $t_3 = -P/7K$ whence:

$F_1 = 4/7P$ or $\sim$ 57 % P

$F_2 = 2/7P$ or $\sim$ 29 % P

$F_3 = 1/7P$ or $\sim$ 14 % P.

(It can be shown that besides these reactive forces which are induced on the abutment teeth by the load on the pontic, each abutment tooth also has the reactive force to the direct functional force applied to its own chewing surface, provided that these direct forces have approximately the same magnitude for each abutment.)

Similar analysis of the two-abutment bridge shows that:

$F_1 = 50\ \%\ P, \qquad F_2 = 50\ \%\ P,$

and for the four-abutment bridge the reactive force on each abutment is increased by 25% P.

4. *Stresses on Fixed Bridges.*—The method used in Appendix 2 when applied to the results of Appendix 3 gives the strain and bending moment at each soldered joint of the fixed bridge. Let $S_{1p}$, for example, represent the joint between the first abutment tooth and the pontic, $M_{23}$, the bending moment between the second and third abutments, etc. Then for the two-abutment bridge:

$S_{1p} = P/2 \qquad M_{1p} = aP/4$

$S_{p2} = P/2 \qquad M_{p2} = aP/4$

For the three-abutment bridge:

$S_{1p} = 4/7\ P \qquad M_{1p} = 2/7\ aP$

$S_{p2} = 3/7\ P \qquad M_{p2} = 5/14\ aP$

$S_{23} = 1/7\ P \qquad M_{23} = 1/14\ aP$

For the four-abutment bridge:

$S_{12} = P/4 \qquad M_{12} = aP/8$

$S_{2p} = P/2 \qquad M_{2p} = aP/2$

$S_{p3} = P/2 \qquad M_{p3} = aP/2$

$S_{34} = P/4 \qquad M_{34} = aP/8$

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# A METHOD OF PRODUCING DISPLAY MODELS

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*Washington, D.C.*

MANY INTERESTING and abnormal mouth conditions are encountered during the routine practice of dentistry, and an efficient technique for the production of inexpensive display models would preserve these conditions for teaching and demonstration purposes.

Stone or plaster casts have been used extensively for making models, but this material chips easily and does not reproduce the natural pigmentation of the mouth. Although painting increases the natural appearance of these casts, it does not improve their friability. Models made of dental plastics with natural colored teeth and pink alveolar ridges and bases are lifelike in appearance, but construction has been expensive and time consuming, which has made their production impractical for most practitioners.

The evolution of autopolymerizing plastics, however, has made the production of these models quick, easy, and inexpensive. They are also excellent reproductions of the original casts, and admirably withstand the rigors of travel and handling.

## THE PRODUCTION OF AN AUTOPOLYMERIZING PLASTIC MODEL

1. An accurate impression of the oral condition to be reproduced is made, and a stone cast is poured. The cast is then trimmed to the exact dimensions desired in the final display model (Fig. 1).

2. The cast is duplicated in a suitable duplicating flask with an agar-agar base duplicating material. The agar-agar material is thoroughly chilled and the cast is carefully removed (Fig. 2).

3. A thin mix of tooth colored autopolymerizing resin is poured into the tooth portion of the duplication mold. When the resin has set, the teeth are removed from the mold, and the excess plastic, representing gingival tissue, is carefully trimmed away. The trimmed teeth are reseated into the duplication mold and placed in the refrigerator for one hour (Figs. 3, 4, 5).

4. The duplication mold is removed from the refrigerator, and any condensed moisture is removed with compressed air. The duplication mold is filled with a thin mix of pink colored autopolymerizing resin and returned to the refrigerator where it should remain for ten hours. The refrigeration increases the setting time

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Fig. 1.

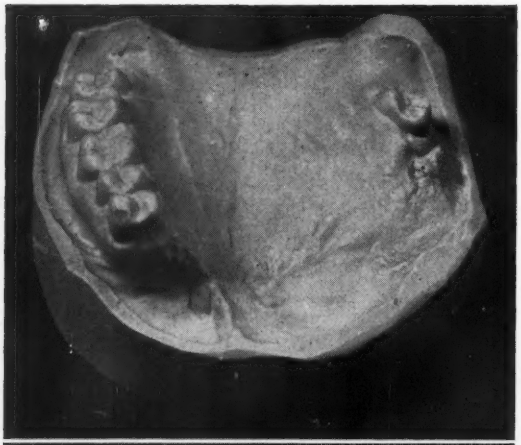

Fig. 2.

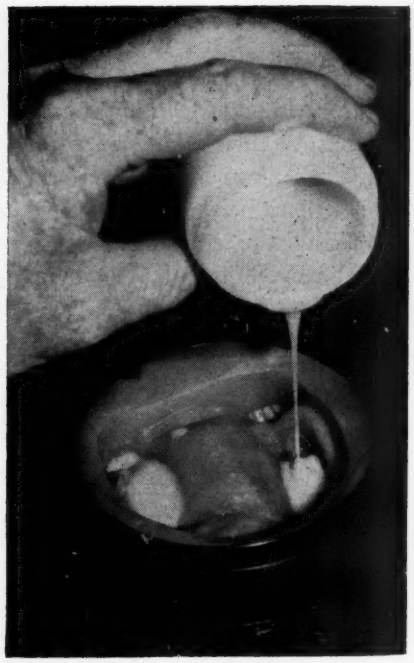

Fig 3.

Fig. 1.—The master stone cast.

Fig. 2.—The agar-agar duplication mold of the master stone cast.

Fig. 3.—Pouring tooth-colored autopolymerizing plastic into the tooth portion of the agar-agar duplication mold.

Fig. 4.

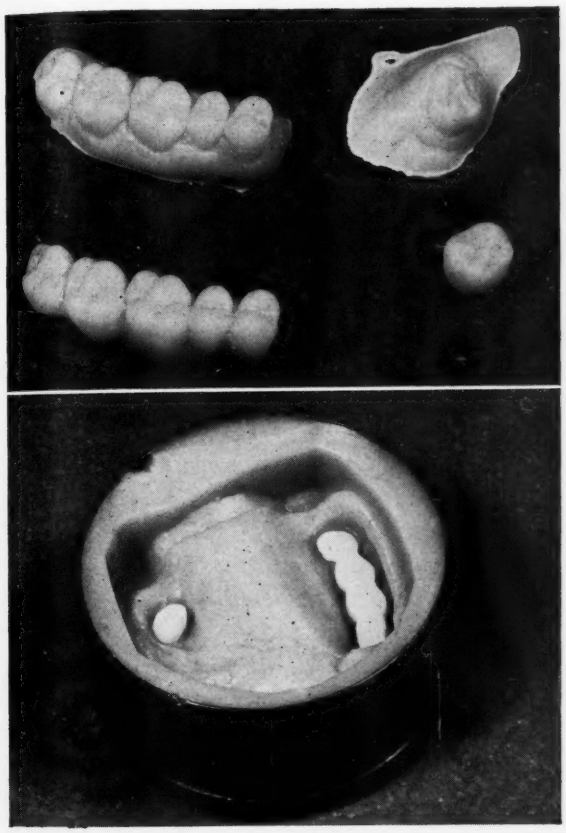

Fig. 5.

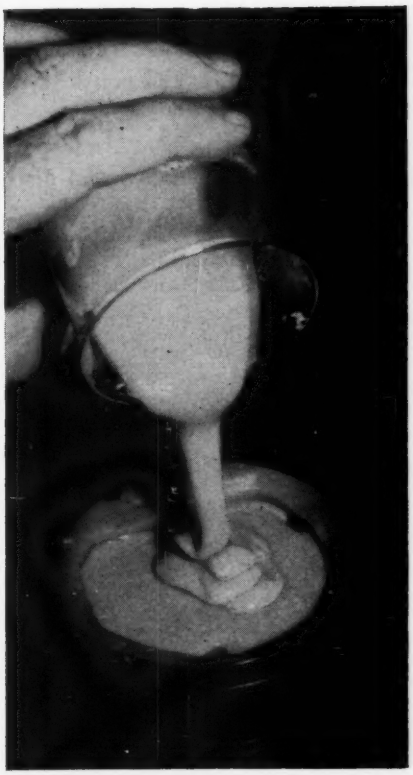

Fig. 6.

Fig. 7

Fig. 4.—The polymerized tooth-colored plastic removed from the duplication mold. The upper excess is untrimmed. The lower excess has been carefully removed with burs.

Fig. 5.—The trimmed polymerized tooth-colored plastic replaced into the agar-agar duplication mold.

Fig. 6—Pouring pink autopolymerizing plastic into the thoroughly chilled agar-agar duplication mold.

Fig. 7.—The final plastic model.

of the autopolymerizing resin. The exothermic heat produced by the setting of the resin is spread over a longer period of time, resulting in a final model unmarred by porosity (Fig. 6).

5. The set plastic model should be removed, the base trimmed as necessary, and the entire model polished (Fig. 7).

The model produced by following this technique is dense and colorful. There is little or no porosity, and the line of differentation between the tooth and the gingivae appears sharp and distinct. The models are excellent for demonstration and teaching purposes.

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# COMPLETE DENTURE FOR THE CONGENITAL CLEFT PALATE PATIENT

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TOO OFTEN, EVEN the men who specialize in prosthodontics shy from the edentulous cleft palate patient. This, I believe, is because the problems are viewed much after the manner of the fellow who could not see the forest for the trees.

If we consider the factors that lead to a prognosis for the edentulous patient, we will find more in favor of a successful result for the majority of the cleft palate patients than we will for many of our normal patients. The factors which favor the success of edentulous cleft palate restorations are: (1) In all congenital cleft palate patients involving the ridge, we find an underdevelopment of the maxilla. This means that throughout the entire life of the patient, the mandibular movement has been more or less a retrusive, rather than the protrusive thrust so often found in the normal patient. This tends to seat the denture. (2) The patient has never been able to use the anterior teeth. This tends to limit mandibular movement, and thus reduces the forces that displace a denture. (3) The patient with an underdeveloped maxilla very seldom has good occlusion of the posterior teeth. This tends to reduce the development of power in the muscles of mastication, which in turn tends to reduce the stresses that may be placed upon the denture.

The factors which are unfavorable to the success of the appliance are (1) the reduced area of hard tissue contact and (2) the additional weight of the appliance and the lever arm of the tailpiece and obturator.

## EXAMINATION

The prosthodontist must, in turn, examine each structure in the mouth of the cleft palate patient, just as the forester must examine each tree to determine the kind of a forest with which he is dealing. The palate of the patient is either an unoperated or a postoperated palate. Since there may be so many difficult ramifications in a postoperated palate, this article will be limited to the treatment of the unoperated edentulous congenital cleft palate patient.

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The type of the cleft should be classified, and the relation of the hard structures noted, as follows:

*Class 1.* Cleft of the soft palate only.

*Class 2.* Cleft of the soft and hard palate, not involving the ridge.

*Class 3.* Cleft of the soft and hard palate extending through the ridge at the junction of the premaxilla and the maxillae.

*Class 4.* Cleft of the soft and hard palate extending through the ridge on both sides of the maxilla and freeing the premaxilla.

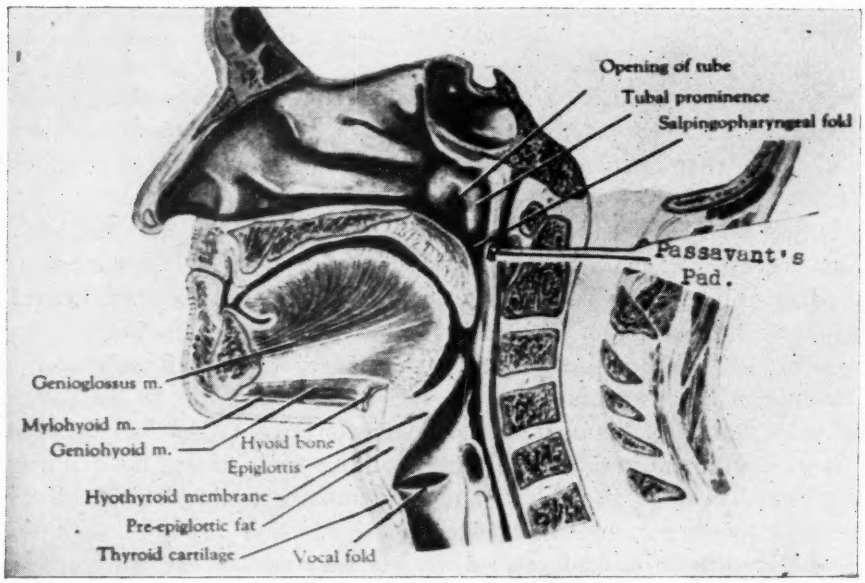


Fig. 1.—Passavant's pad (Revised from Sicher, Harry: Oral Anatomy, St. Louis, 1949, The C. V. Mosby Company, p. 179.)

The posterior pharyngeal wall is examined. This is the back wall of the throat immediately behind the region that is normally occupied by the uvula. The purpose of this examination is to note the exact location of the more or less prominent projection on the posterior pharyngeal wall, known as Passavant's pad (Fig. 1). During the act of swallowing, the upper fibers of the superior constrictor muscles cause an upward, and generally an inward, or "toward the center," movement of the soft tissues of the posterior pharyngeal wall, that forms a crescentlike fold or ridge at or below Passavant's pad. The fold or ridge, as the case may be, caused by the swallowing act is known as Passavant's cushion or ridge. It is the upper border of Passavant's cushion or ridge that will be used to contact the distal and lower border of the bulb of the obturator. The point of movement and the amount of movement in this region should be determined. The ease of movement in this region will give us a clue as to the difficulty involved in sealing off the nasopharynx from the oral pharynx.

Many cleft palate patients can swallow voluntarily with the mouth open. When this cannot be accomplished, a blunt instrument is used to tease the posterior pharyngeal wall until the complete swallowing act is accomplished. This act is

repeated several times, and the exact location of the fold is noted and marked with an indelible pencil.

The movements of the soft palate remnants are observed next. Their upward and inward movements, as well as the start of the movement at the junction of the soft and hard palate, are noted and marked with an indelible pencil. The marking of the start of the movement of the tissue at the junction with the hard palate must be accurate, as this is to limit the distal extension of the denture which is to support the obturator. We cannot seal the denture beyond this point with safety.

The area to be covered by the denture is examined next to note the relation of the cheeks, lips, and frenula to the alveolar ridge, and the relation of the mandible to the maxilla.

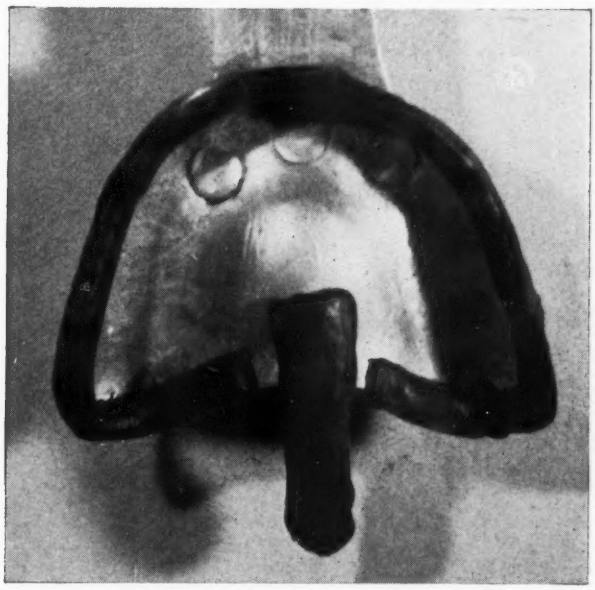

Fig. 2.—The tray and wax extension.

## STUDY CASTS

Impressions for study casts require careful preparation of the tray and selection of the impression material. The denture-bearing area, the soft palate, and the posterior pharyngeal wall must be included in the upper cast. A flexible aluminum stock tray is selected to fit the denture-bearing area in the usual manner. Quite often, because of the inhibited growth of the maxilla, it is necessary to shorten the tray distally, and to build up the buccal and labial flanges. This is done with utility wax which will stick to the dry surface of the tray without heating, and is easy to manipulate. A tailpiece of utility wax is added to the palatal side of the vault of the tray. It is directed toward Passavant's pad on the posterior pharyngeal wall. The tailpiece is extended into the cleft, but it must not touch any of the tissues in the cleft when the patient is in an upright position with the head bent forward, or during swallowing (Fig. 2).

The material selected for the impression is one that will not displace the soft tissues. One of the tough alginates may be used. The proper mixing and handling of the alginate impression material is necessary to insure good results. This point is emphasized because there is a critical period during which some of the alginates will completely surround the delicate structures in a cleft palate, will adapt, but will not adhere. It may then be removed without distortion or breaking. If the material should break, the broken piece may be removed with ease and pinned to the impression. If the alginate impression material is not handled properly, the impression will not be successful. Because of the physical properties of the alginate materials, the impression must be free of all salivary and nasal secretions, and it must be poured in stone immediately. The cast must be placed in water to set.

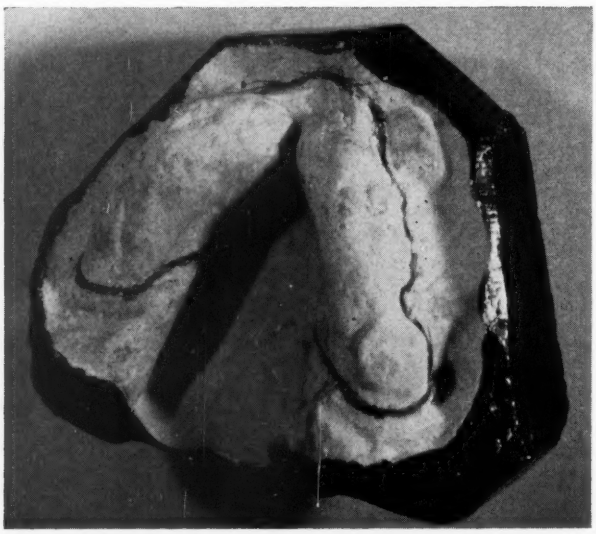

Fig. 3.—A marked cast with the frenula and the movable soft tissue outlined.

When the cast is set, an accurately fitted hard baseplate is adapted to the hard palate area of the cast. In making the outline for the baseplate, the buccal and labial frenula must be considered carefully. The beginning of movement of the soft palate remnants requires particular attention. These extend a considerable distance into the cleft in the hard palate area in some patients (Fig. 3).

## JAW RELATIONS

A modeling compound occlusion rim is added to the hard baseplate. Then the vertical opening is registered carefully. Because of bad speech habits and the overclosure generally present in the cleft palate patients, the use of phonetics in determining the correct vertical opening is unreliable. Niswonger's discovery that the "rest position" is retained throughout life is just as true in the cleft palate patient as it is in the normal patient. The cleft palate patient seems to be able to assume the rest position of the mandible with greater ease than many normal patients.

The rest position is located, and the modeling compound occlusion rim is trimmed to allow for about 4 mm. of free-way space in the incisor region. This is tested by having the patient close and swallow. That position in which the patient can swallow with the greatest ease is considered to be the correct vertical opening.

The labial surface of the occlusion rim is then contoured for esthetics, either by adding soft wax or carving the modeling compound. Centric relation is registered, and the baseplate with the occlusion rim is removed from the mouth, chilled and dried.

### THE FINAL IMPRESSION

Low-fusing stick modeling compound is traced on the border of the baseplate, one section at a time, until we have completed the border seal. If the cleft involves the ridge, each section of the ridge is sealed as a unit. When the premaxilla is free and movable, the border seal is not permitted to extend onto the premaxilla. The premaxilla is covered but not sealed.

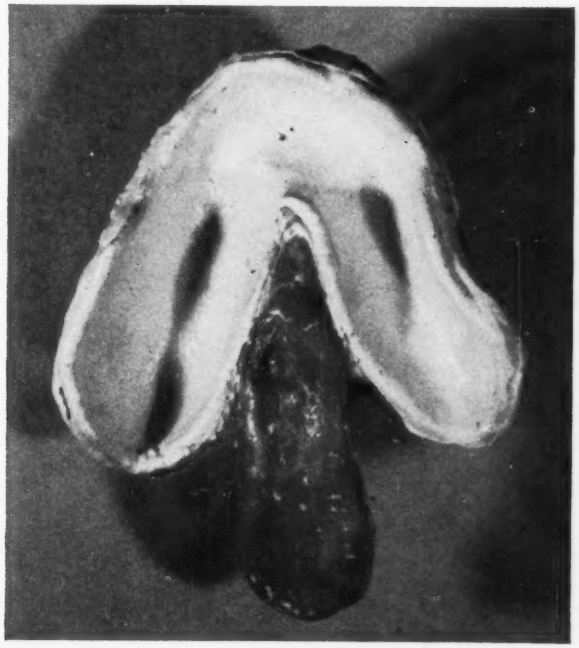

Fig. 4.—A zinc oxide and eugenol impression of the hard palate area.

The baseplate with occlusion rim is returned to the study cast, and a tailpiece is seared to the baseplate. The tailpiece extends distally to the end of the uvula and approximates, but does not touch the cast. This is carried to the mouth and adjusted so it does not touch the tissues in the soft palate region when the patient rests the chin on the chest, and swallows.

When the tailpiece is adjusted so it does not touch the soft tissues, the baseplate is removed from the mouth and dried. A thin mix of zinc oxide and eugenol impression material is spread evenly over the hard palate area of the baseplate.

This is seated in the mouth with as little pressure as possible. The patient is directed to open the mouth wide, and to move the mandible laterally several times, then to release the pressure. When the impression material has set, centric relation is checked and corrected if necessary. The impression is then removed from the mouth, and any impression material that may have extended onto the tailpiece is removed (Fig. 4).

The tailpiece is dried, and an even creamy mix of the zinc oxide and eugenol impression material is spread on the tailpiece. The impression is placed in the mouth, and the patient is asked to close tightly. Care must be exerted to see that the patient's jaw is closed in centric relation. The patient is then directed to force the chin down on the chest and swallow, then bend the head to each shoulder and swallow, and return the chin to the chest and hold the jaw tightly closed until the impression material is set (Fig. 5).

Fig. 5.—The position of the head when the impression of soft palate area is made.

A face-bow registration for mounting of the upper cast is made while the impression is still in place. The face-bow will prove its worth when mounting casts of cleft palate patients.

The impression is removed and examined to see that there is no overlapping of the impression materials (Fig. 6). The impression of the hard palate region should have a good border seal, and the impression of the soft palate region should be clear-cut and unstrained, and should show the maximum pull of the remnants of the soft palate. Any surplus of impression material that may extend into the cleft is trimmed off, with the exception of that in the region of the uvula. The impression is poured in stone and placed in water to set.

The lower cast is mounted on the articulator, and the teeth are set up and "tried in" for esthetics. After the teeth are satisfactorily arranged, the next consideration is the waxing of the palatal surface of the denture.

The purposes in constructing an obturator for the cleft palate patients are: first, the successful closure of the cleft, second, improvement of esthetics, and third, the formation of a palate that will aid in deglutition, articulation, and the development of normal speech.

The organs which enter into the mechanism of speech and deglutition must be given consideration in outlining the form of the palate. The contour of the soft and hard palate, the denture base material and its relation to the teeth, the teeth and their relation to the lips, and the manner in which the tongue contacts these contours are the forms that aid in the development of normal speech. The obvious way to meet these requirements is to duplicate as nearly as possible the palatal contours of a cast of a dentition similar to that of the cleft palate patient.

When the denture has been waxed satisfactorily, it is flasked, processed, and finished.

Fig. 6.—The zinc oxide and eugenol impression of the hard and soft palate regions.

## THE OBTURATOR IMPRESSION

The surplus denture base material in the region of the uvula, which outlines the constriction of the soft palate remnant, is drilled to receive and stabilize the bent ends of an 18 gauge wire loop (Fig. 7). The wire loop is to support the impression for the obturator. The denture is tried in the mouth, and the wire loop is bent so it is directed toward Passavant's pad. The wire loop must be short enough so that the patient cannot feel it under any condition.

Sticky wax is seared to the wire, and Iowa impression wax is wrapped around the sticky wax. An excess of the wax is pointed toward Passavant's pad. The excess wax will induce swallowing and produce a clear impression of the action

of the soft tissues of the posterior pharyngeal wall. The denture is removed and dried, and an excess of impression wax is added to one side of the wax mass. The patient is instructed to force the head to the shoulder opposite the side on which the excess wax has been placed. The patient is directed to swallow until he is not conscious of the wax. This operation is repeated on the other side. The excess wax is removed, and tested for seal (Fig. 8).

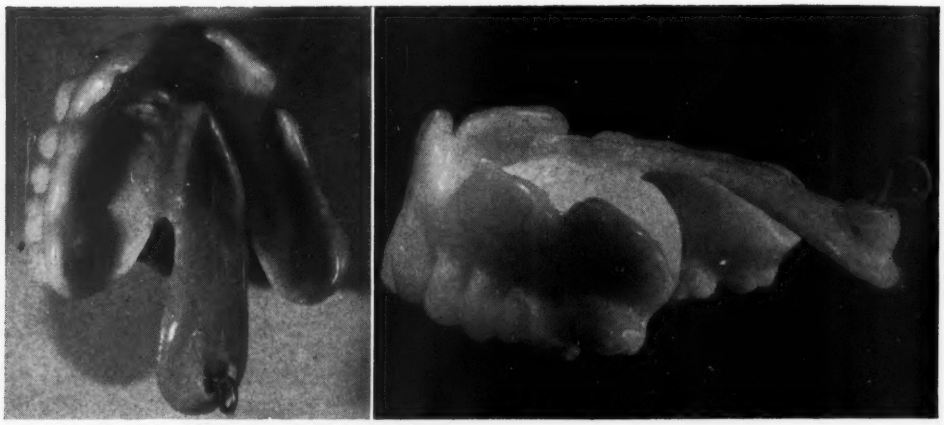

Fig. 7.—The completed denture with a wire placed to stabilize the wax impression for the obturator.

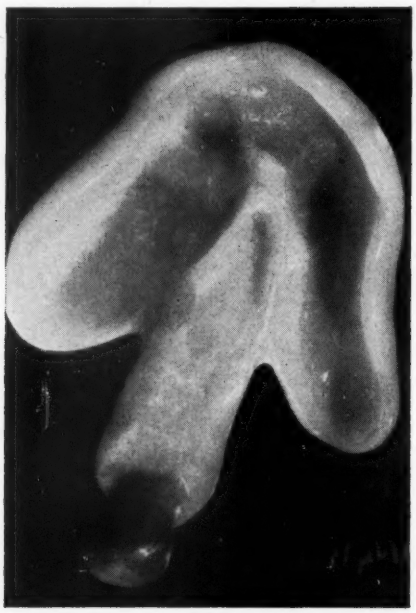

Fig. 8.—The denture with the wax impression for the obturator completed.

## TEST OF THE IMPRESSION

The impression is tested by having the patient attempt to blow the nose with the lips open, and having him blow up a toy balloon, and gargle the throat with warm water, and drink a glass of cold water without stopping.

When these tests are satisfactory, the wax impression is chilled and removed. It is then washed free of all nasal and salivary secretions (Fig. 8).

### CAST POURING

Stone is poured into the tissue side of the denture to the level of the undercut flanges (Fig. 9). It is placed in water immediately to prevent distortion of the wax impression for the bulb. When the stone is set, its surface is treated with a separating medium, and the wax impression is surrounded with stone. The stone which surrounds the bulb is extended onto the stone in the denture. When the second pour of stone has set, it is trimmed for flasking.

Fig. 9.—Stone is poured into the denture to relieve the undercuts. The denture and obturator impression are ready for flasking.

### FLASKING THE HOLLOW BULB

Two flasks that have interchangeable tops are selected. The bulb portion is invested in the bottom half of Flask 1, so the denture will be in the top half of the flask. Separating medium is applied, and the flasking is completed in the top half of Flask 1.

When the flasking stone is set, the flask is warmed and separated, and all of the wax is removed from the flask. After the flask is cool, the bulb form is lined with a single thickness of baseplate wax (Fig. 10). Iowa impression wax is seared to the edge or rim of this baseplate wax. The top half of Flask 1 is placed in position, and held under pressure until a sharp marginal outline, or impression, of the wax form contact with the tailpiece of the denture is developed. Then the top half of the Flask 1 (the part containing the denture) is removed.

Stone is poured into the hollow wax bulb form, and a wood screw is inserted to act as a reinforcement for the stone in the neck of the bulb. The stone is bridged across the opening, and shaped so that it will remain in the bottom half of the flask when the flask is separated (Fig. 11).

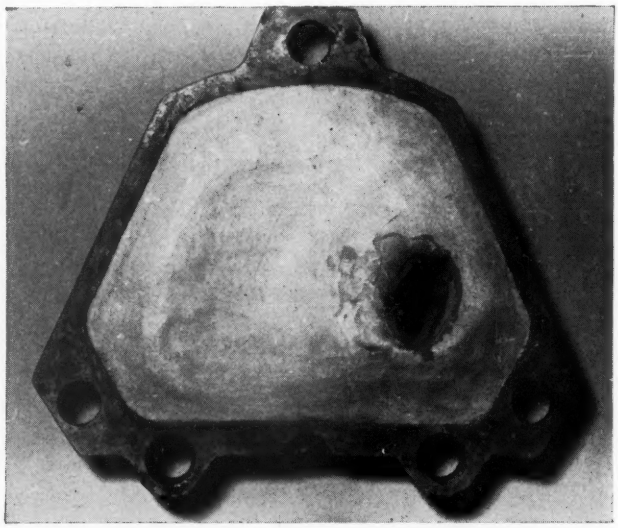

Fig. 10.—A single thickness of baseplate wax is adapted in the flasked mold of the bulb.

Fig. 11.—Stone core in mold. A wood screw is placed in the stone core for reinforcement.

Separating medium is applied to the stone in the bulb form. The top half of Flask 2 is placed in position, and the flasking is completed. When the flasking stone is set, the flask is warmed, separated, and all wax is flushed from the bulb form. While the flask is hot, the form is flooded with a good liquid "tinfoil substitute." This is held for about two minutes, and the flask is turned down to drain and cool. Since the opening into the bulb form is small, the form is filled with dry acrylic resin powder, and liquid monomer is added until the powder is moist. The trial pack is completed with acrylic resin at the dough stage, and the material is processed in the usual manner.

When the flask is opened, the acrylic resin bulb must remain undisturbed in the lower half of Flask 1. The wood screw is removed with a screw driver, and the stone is chipped from the inside of the acrylic resin bulb.

The top half of Flask 1 (the part containing the denture) is placed in position on the bottom half of Flask 1 which contains the cured bulb form. Any *excess* of acrylic resin on the bulb half of the flask is removed so there is perfect apposition of all metal parts of the flask.

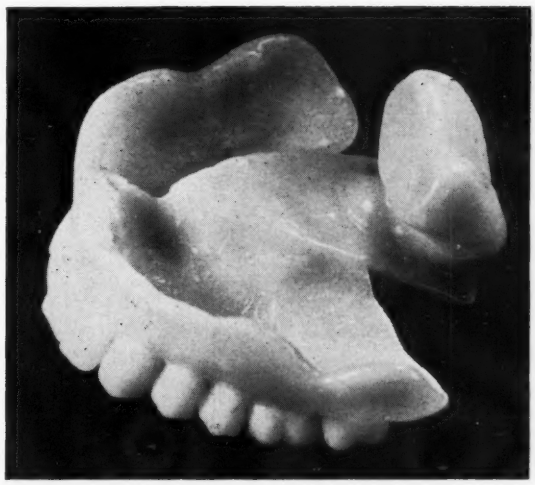

**Fig. 12.—The finished denture with a hollow bulb obturator.**

The contacting acrylic resin surfaces of the bulb, and of the tailpiece of the denture, are freshened with a coarse stone, and a heavy creamlike mix of acrylic resin is applied to the contacting rim surfaces. The flask is closed, and the resin is processed under spring pressure for nine hours at a temperature of 158° F. It *must not* be boiled. If care is used in applying the acrylic resin to the rim of the bulb, there will be very little or no flash or excess acrylic resin to remove after processing (Fig. 12).

## POLISHING

Extreme care must be exercised in polishing the acrylic resin bulb. A highly polished mirror surface is not desired. It should have merely a smooth surface

which can be cleaned easily, and which will make contact with the tissues where needed, and will look well.

The acrylic obturator must be the exact size and form of the wax pattern.

## SUMMARY

If we hope for a successful denture service for the edentulous cleft palate patient, careful consideration must be given the following six steps:

1. A thorough visual and tactile examination.
2. A combination impression of the hard palate area at rest, while the soft palate and pharyngeal regions are functionally active.
3. A complete balance of all occlusal forces.
4. The palatal, base material and tooth contours that aid in normal speech and deglutition.
5. The need for a meticulous processing technique in order that we may get an accurate reproduction of the impressions and palatal contours.
6. Care in the final finishing so that the contours which were so carefully worked out can be retained.

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# INTRAORAL SPLINT FOR SUPPORT OF THE LIP IN BELL'S PALSY

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*Bay Pines, Fla.*

BELL'S PALSY IS A TYPE of facial paralysis due to an affliction of the seventh nerve. This facial paralysis may be the result of disease of the peripheral nerve branches of the facial nerve. It may follow acute respiratory tract infections, such as colds or exposure of the face to cold. The infection may also be caused by a virus or by trauma.

Physical treatment of the facial muscles of every patient with seventh nerve palsy is necessary. Reinnervation of the facial muscles is likely to occur in the majority of patients without the necessity of an operation. However, because of the disuse atrophy and fibrosis that accompany denervation, the quality of the recovery depends directly on maintaining the contractile power of the muscles. In the face, gravity and the pull of the muscles on the side opposite the palsy, acting continuously in the play of facial expression and by voluntary movement, encourage rapid atrophy.

An intraoral splint, with support for the lip attached to the upper teeth of the affected side, or fabricated as a partial denture, or attached to a full upper denture, should be made for patients with facial palsy where the faradic response is found to be negative. This will support the muscles of the affected side while regeneration is taking place. This article is a report of the construction of such an appliance. It was used to support the right corner of the mouth of a patient with Bell's palsy which affected the right side of the face. In this case the support was fabricated in the form of a partial denture.

## TECHNICAL STEPS IN CONSTRUCTION OF THE APPLIANCE

Preliminary impressions for study casts were made with an alginate impression material. The recovered maxillary cast was surveyed, and the appliance was designed. Since this appliance was to support the corner of the mouth, it was necessary to gain all of the clasping support possible. Multiple clasping was employed.

The maxillary teeth were prepared for the reception of a partial denture according to the surveyed cast. The final impression of the maxillary arch for the master cast was made with a reversible hydrocolloid impression material. All impressions were poured in artificial stone.

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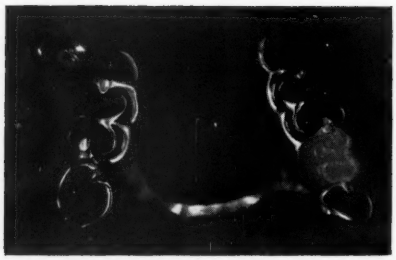

Fig. 1.—The cast splint, ready for the development of the pattern for the acrylic resin overlay.

Fig. 2.

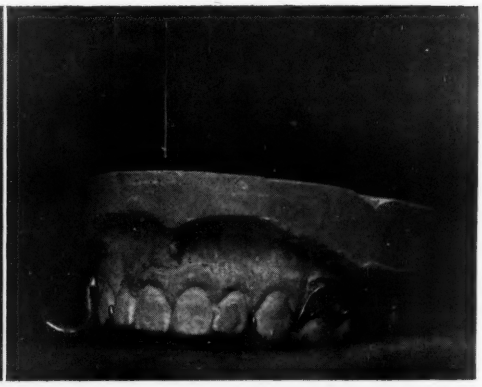

Fig. 3.

Figs. 2 and 3.—The completed splint.

Fig. 4.

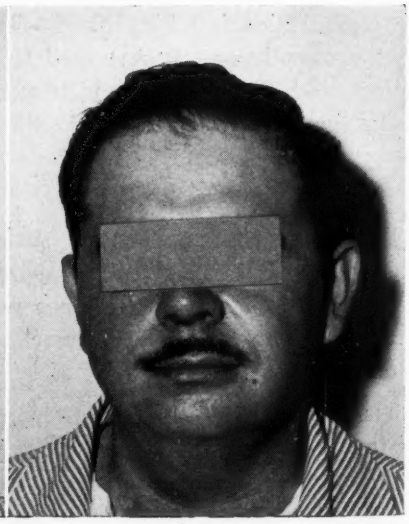

Fig. 5.

Fig. 4.—The patient without the splint. Note the drooping the the right side of the mouth.
Fig. 5.—The patient with the splint in position and supporting the right side of the mouth.

The master cast of the maxillary arch was prepared for the fabrication of the partial denture. The cast was relieved, and undercuts of the teeth to be clasped were blocked out according to the design of the proposed appliance. Then the prepared cast was duplicated by means of a reversible hydrocolloid impression material, and gray refractory investment material to form a refractory cast.

The refractory cast was treated with "model spray" and dried in a casting furnace at 200° F. for one hour. The cast was then developed for the splint casting, using blue casting wax and preformed plastic patterns, following the design of the master cast. An open loop of 8 gauge half-round wax was attached to the splint wax-up on the labial surface between the cuspid and first bicuspid. The loop was inclined anteriorly about 1 mm., and extended below the level of the occlusal plane 2 mm. The open, ringlike extension was approximately one-half inch in diameter. In this case, the loop was attached to the right side of the splint, since it was used to support the right side of the mouth. (Adjustment to the final position was done in the mouth on the gold casting before clear acrylic resin denture base material was added to the loop.)

The wax-up of the splint was invested, cast, recovered, and polished for insertion. Minor adjustments were made on the inserted splint. The loop engaging the corner of the mouth was adjusted for height, direction, and inclination. The purpose of the loop was to reinforce a clear acrylic resin overlay. The loop was covered with pink baseplate wax to develop the pattern for the resin overlay. The final contour and position of the loop and the overlay was developed in the mouth (Fig. 1).

The contoured baseplate wax enveloping the gold loop was replaced with clear acrylic base material by means of routine laboratory procedures for processing this material (Figs. 2 and 3). The splint was given a final polish and inserted in the mouth (Figs. 4 and 5).

## SUMMARY

1. Intraoral splints for facial muscle support in Bell's palsy are necessary as adjunct and supportive treatment, while regeneration of the nerve is taking place.

2. Development of these splints does not require special procedures or laboratory equipment. Their maintenance is negligible.

Acknowledgment is made to Chief Dental Technician, Bates I. Graham, VA Center, Bay Pines, Florida, whose attention to laboratory details made this procedure possible.

VETERANS ADMINISTRATION CENTER
BAY PINES, FLA.

# News and Notes

## ANNOUNCEMENTS

The Pacific Coast Society of Prosthodontists and the American Denture Society will hold a joint meeting at the St. Francis Hotel in San Francisco, Oct. 14 and 15, 1955. The program will be most interesting and valuable.

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The National Association of Dental Laboratories will hold its fifth annual meeting at the Ambassador Hotel in Los Angeles, Oct. 14-16, 1955. All dental laboratory men, dentists, and dental tradesmen are invited to attend this meeting.

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The meeting of the German Society for Jaw and Face Surgery will be held in Hamburg, Germany, July 27-30, 1955.

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The 43rd Annual Meeting of the Federation Dentaire Internationale will be held in Copenhagen, Denmark, Aug. 14-20, 1955. For full information and reservations write to W. Riis Klausen, 1, Alhambravej, Copenhagen V.

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The Dental Department of Beth Israel Hospital announces a course in "Occlusal Adjustment" to be given Sept. 28 to Oct. 2, 1955, and a seminar on periodontia, Oct. 31 to Nov. 11, 1955. The courses will be given under the direction of Henry M. Goldman, D.M.D., and Bernard Chaikin, D.M.D. For further information write to Coordinator of Education Programs, Beth Israel Hospital, 330 Brookline Ave., Boston 15, Mass.

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The Ohio State University College of Dentistry announces that it is receiving applications of students for the Curriculum of Dental Laboratory Technology. This course of study of the laboratory phases of prosthodontics extends over two academic years and leads to a Certificate of Graduate Dental Laboratory Technologist. For further information write to the Director of Dental Laboratory Technology, Ohio State University College of Dentistry, Columbus 10, Ohio.

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The next annual meeting of the American Academy of Crown and Bridge Prosthodontics will be held at the Conrad-Hilton Hotel, Chicago, Ill., Feb. 4-5, 1956.

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The next annual meeting of the American Academy of Restorative Dentistry will be held at the Conrad-Hilton Hotel, Chicago, Ill., Feb. 4-5, 1956.